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81

MELBOURNE UNIVERSAL EXHIBITION

1880

FRANCE

NOTICES

ON

THE DESIGNS, MODELS AND WORKS

PERTAINING TO THE SERVICES

OF THE "PONTS ET CHAUSSÉES", THE MINES

AND THE PUBLIC EDIFICES AND NATIONAL PALACES

COLLECTED

BY THE MINISTRY OF PUBLIC WORKS

TRANSLATED BY DAVID COALES

PARIS

NATIONAL PRESS

M DCCC LXXX

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186 e 15

INTRODUCTION.

The Government of France has made it a point of honour to be represented at the successive International Exhibitions, which have taken place during the last fifteen years.

In accordance with numerous antecedents, the Minister of Public Works has ordered a collection of designs, models and works to be made and sent to Melbourne. These objects have been selected with the view of imparting a knowledge of the operations of the « Ponts et Chaussées », the Mines, and the principal branches of the Central Administration during the least few years.

The recent date of the Universal Exhibition of 1878 precludes the possibility of sending to Melbourne a number of objects entirely new to the scientific world. It has therefore been considered expedient to restrict the collection to the most remarkable and most recent works, although some of these may already be partially known.

The period of time for the preparation of designs, etc.,

being extremely limited, the Ministry has been compelled to renounce several plans, and to be satisfied with sending general views of the greater number of the objects exhibited.

As some compensation for the insufficiency of the details, this volume is illustrated by numerous engravings, which will be found to facilitate a perfect comprehension of the designs, models, etc.

The concise explanations given of the most interesting details, are thus rendered additionally clear, and engineers will find, in a condensed form, much valuable information of a practical nature.

The present volume is divided into three par :

FIRST PART.

«PONTS ET CHAUSSÉES.»

1st section. — Roads and bridges.
2nd section. — Hydraulic service.
3rd section. — Internal navigation.
4th section. — Maritime works.
5th section. — Lighthouses and beacons.
6th section. — Railways.
7th section. — General documents.

SECOND PART.

MINES.

Unique section. — General documents. — Experimental geology. — Synthetic geology. — Geological chart of France.

THIRD PART.

PUBLIC EDIFICES AND NATIONAL PALACES.

The text of the present catalogue has been most carefully translated into English. The execution of this work has been confided to M. David Coales, translator, and it forms a volume by itself, specially intended for countries where the English language is spoken.

The exhibition pertaining to the Ministry of Public Works, has been organized by a Commission presided over by the Under Secretary of State, M. Sadi Carnot, and consists of the following gentlemen :

MM. Allard, Inspector general « des Ponts et Chaussées », Director of the Central Lighthouse Service;

Colligxon, engineer in chief « des Ponts et Chaussées », Inspector of the « École des Ponts et Chaussées »;

Dartein (De), engineer in chief « des Ponts et Chaussées », Professor at the « École des Ponts et Chaussées »;

Daubrée, Inspector general of Mines, Director of the School of Mines;

Demanche, Director of the Personnel and of Mines at the Ministry of Public Works;

Dupont, Inspector general of Mines, Inspector of the School of Mines;

Durand-Claye, engineer in chief « des Ponts et Chaussées », Professor at the « École des Ponts et Chaussées »;

Lalanne, Inspector general « des Ponts et Chaussées », Director of the « École des Ponts et Chaussées »;

Picard, engineer in chief « des Ponts et Chaussées », Director of the cabinet of the Minister of Public Works;

Rousseau, engineer in chief « des Ponts et Chaussées », Director of Roads and Navigation;

Véron-Duverger, Inspector general « des Ponts et Chaussées », Director general of Railways;

Chemin, engineer « des Ponts et Chaussées », Professor at the « École des Ponts et Chaussées » and Secretary to the Commission.

Under the direction of M. Lalanne, two members of the Commission, M. de Dartein and M. Chemin, have been appointed to superintend the organization of the exhibition, and the preparation of designs, works, catalogues, etc. M. Boulard, chief of the design department of the « École », has ably assisted them in the undertaking.

M. Journet, engineer « des Ponts et Chaussées », has been sent to Melbourne, for the purpose of directing the installation of the exhibition of the Ministry of Public Works, and will furnish all the necessary information and explanatory details, that may be desired by foreign engineers or visitors to the Exhibition.

PREFACE

BY THE TRANSLATOR.

In 1876, the writer had the honour of being appointed to execute a translation of the Catalogue of the «Ponts et Chaussées» for the Universal Exhibition at Philadelphia, and in the preface to that work, he intimated his conviction that it was «an imperative duty to follow the French text with rigorous exactness». The favourable reception accorded to that translation, by American engineers, has confirmed this opinion, and in the present volume the same course has been followed, allowance being made for idiomatic difficulties.

The Catalogue now presented to the notice of Australian engineers and scientific persons, is of a more elaborate and comprehensive description, and the translator deems it incumbent upon him to offer a few explanations which may be serviceable to English readers.

It will be observed that the French term « École des Ponts et Chaussées » is retained throughout the volume, and the following reasons will doubtless afford a satisfactory explanation of this course. There is no institution in England of an analogous character; though essentially a Government institution, the « École » possesses no administrative authority, but from it may be said to emanate nearly all the engineering knowledge of the country, with the exception of that branch which exclusively concerns the military profession, and no work of public importance is undertaken, before being submitted to the General Council « des Ponts et Chaussées ». An Englishman will be able to form a tolerably correct idea of the responsibility, by supposing the Board of Works, the Metropolitan Board, the Trinity Board, and other bodies of the same character, all incorporated into one institution. It is, in short, a College of Engineers of the highest class, and such being the case, it appeared preferable to retain the designation « École des Ponts et Chaussées ».

A few other French terms in this work, appear to require some explanation. The word *barrage* is now generally employed by English engineers, as indicating a dam of an elaborate description. The word *béton* is used, because, while in all respects used as concrete, it is made in a different manner. The terms *bossage*, *revetment*, and others of a similar nature, are

now commonly used in England, and will be found in Gwilt's Encyclopædia of Architecture. The term *réseau* may mean a network or reticulated system of any kind, or an entire or partial triangulation. It remains to notice the word *conducteur*, to which the English word *conductor* has scarcely any relation. A «conducteur» is one who is permitted to enter the «Ponts et Chaussées», without passing through the Polytechnic School, and in order to attain the position of an engineer, he has to undergo a long probation and many difficult examinations.

The wide range of subjects, embraced in this translation, has necessitated reference to a great number of works, among which may be cited Gwilt's Encyclopædia, mentioned above, Spon's Dictionary of Engineering, Sir Charles Lyell's Principles of Geology, besides those of other French and English authors of celebrity. Some errors may doubtless exist, but it is hoped that they are neither numerous nor important, since no efforts have been spared to render this volume worthy of French science, and acceptable to the engineers of the great and flourishing colony of Victoria.

Cordial acknowledgments are due to M. Chemin, engineer «des Ponts et Chaussées», and secretary to the Commission appointed by the Minister to organize the exhibition of the Ministry of Public Works. To the

valuable and intelligent assistance rendered by this gentleman, the translator is indebted for the elucidation of many important and difficult points.

Thanks are also due to M. Schwebelé, Librarian, to M. Witcomb, Professor of English at the Ecole, and to M. Emmanuel Tronquois, architect.

DAVID COALES,

TRANSLATOR.

FIRST SECTION.

ROADS AND BRIDGES.

I

ANDELYS BRIDGE,

ON THE SEINE.

(DEPARTMENT OF THE EURE.)

DEPARTMENTAL ROAD N° 15.

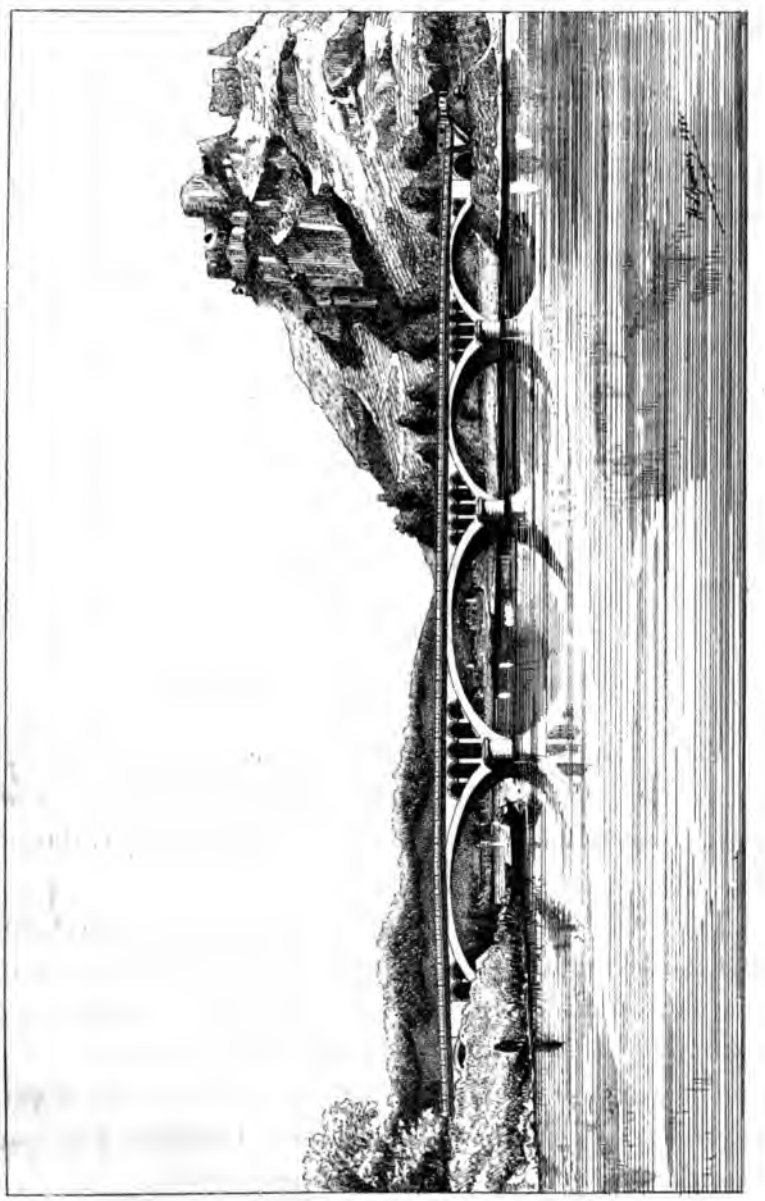
View of the bridge and its approaches.

This bridge was constructed for the service of the departmental road N° 15 (Eure) and occupies the place of a suspension bridge which was destroyed in 1870, during the war.

The total length, including the abutments, is $181^{m},60$, and the breadth at the crown $7^{m},20$; the measurement in the clear, between the parapets, is $6^{m},70$, comprising a roadway of $5^{m},10$ and two footways of $0^{m},80$ each.

The bridge is composed of four basket-handle or elliptical arches, separated by piers $3^{m},50$ in thickness. The span of each arch is 34 metres and the rise $8^{m},80$.

The thickness at the keystones is $1^{m},10$ and the spring-



ers are $0^{m},50$ above low-water mark. The spandrels are hollowed in a transversal and longitudinal direction by semi-circular arches $2^{m},10$ in diameter, supported by square pilasters of various heights and $0^{m},70$ square at the top.

A semicircular discharging arch, with a span of 7 metres, is formed in each abutment.

The piers are laid on solid masses of beton run into bottomless caissons, which rest on a compact bed of chalk. This bed was laid bare by dredging and its surface is 6 or 8 metres below the level of the lowest tides.

The pile foundations of the old suspension bridge were utilized for the abutments, by adding a row of twenty piles on each bank.

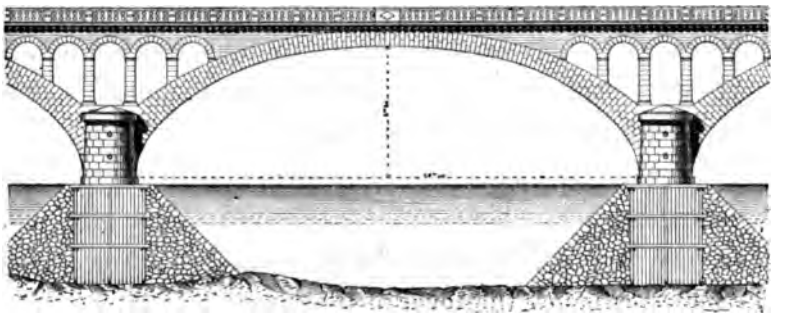
The Government grant 200 000 francs for the execution of the work, only representing the value of the old suspension bridge destroyed during the war, and a fixed bridge being urgently required, it was found necessary in the survey of the plans to adopt arrangements consistent with a reduction of the cost to the lowest possible sum, on account of the very limited resources at the disposal of the department.

With this view, the hollowing of the spandrels was extensively practised, and with the exception of the keystones, which are in dressed stone from Vernon, the entire work is in ordinary masonry.

Cement mortar was used for the great arches only. In all the other parts of the bridge, including the beton foundations, ordinary mortar of hydraulic lime from Senonches or Bougival has been employed.

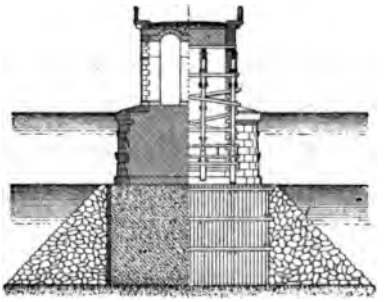
The total cost only amounted to 290 $782^{f},22$, comprising

278 833f,51 contract work and 11 948f,71 expenses of superintendence

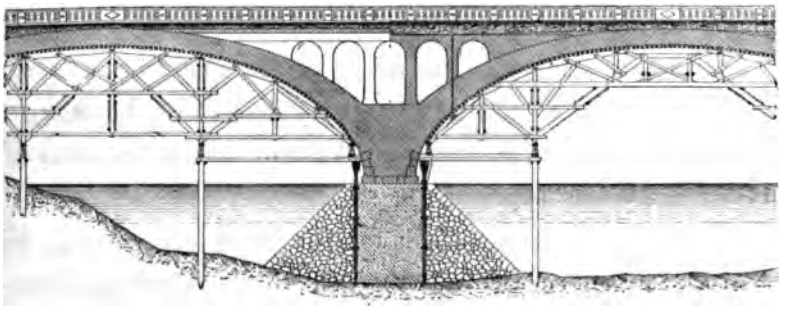


Elevation of a navigable arch.

Transversal half-section of a pier.



Transversal half-section of an arch.



Centres and longitudinal sections.

Taking into consideration the dimensions of the work,

these amounts show an average cost of 1 601f,22 per metre run, and 222f,39 per metre superficial.

The work was commenced in May 1872, finished in November 1873, and on the 1st of December following, the bridge was opened to the public.

The plans were designed and the works directed by M. Degrand, engineer in chief, and by M. Cordier, engineer «des Ponts et Chaussées». M. Chupeau-Hauteville was the «conducteur», and M. Dupont, the contractor.

II

CLAIX BRIDGE,

ON THE DRAC.

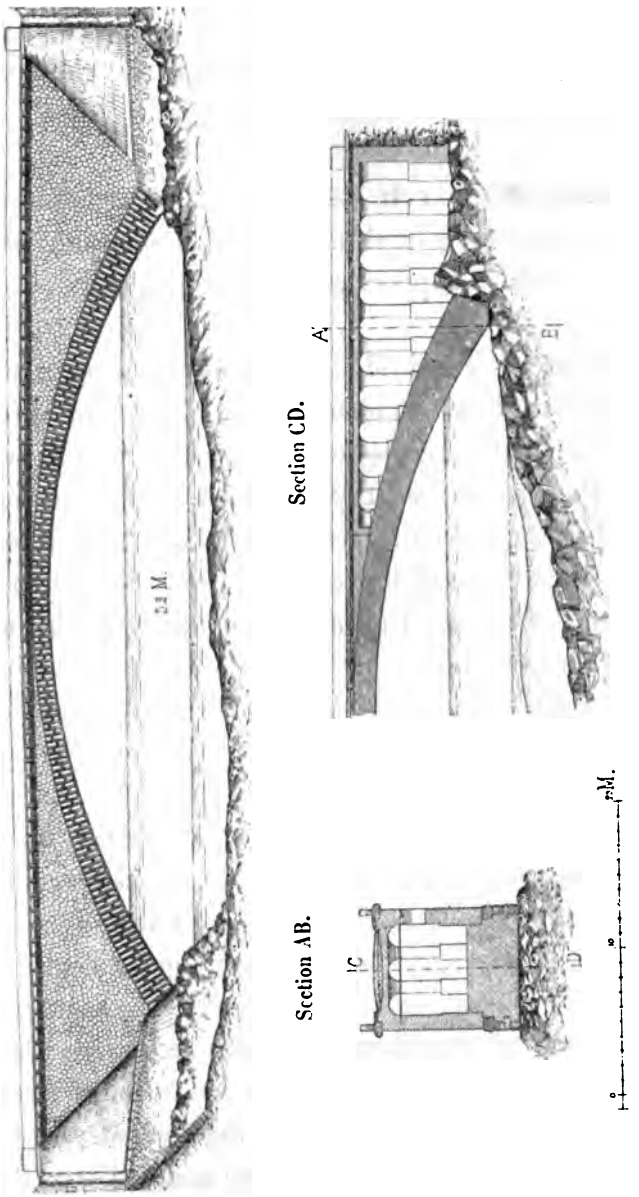
(DEPARTMENT OF THE ISÈRE.)

NATIONAL ROAD N° 75.

Exterior form of the work. — Claix bridge is situated 8 kilometres south of Grenoble, and its exterior presents the form of a single depressed circular arch with embedded abutments. The span of the arch is 50 metres, the rise $7^{m},40$ and the radius 46 metres. The bandeaux are in Sassenage ashlar, faced with bossages. Their thickness at the key is $1^{m},20$ and at the springers $2^{m},20$. The extrados follows the arc of a circle with a radius of $54^{m},40$, and is surmounted by spandrels in uncoursed rubble. The spandrels are crowned by a plinth in ashlar and a rounded coping.

The connection of the bridge with the adjoining embankments is effected by quarter cones, partly turfed and partly stone-packed.

Actual dimensions of the arch. — The real span of the arch is 52 metres, with a thickness of $1^{m},50$ at the key and $3^{m},10$ at the springers. The extrados follows the arc of a circle with a radius of $58^{m},30$. The breadth is $8^{m},20$ between the embossings of the heads. The courses from the springers are carried directly on to a rock of schis-


33 M.
Section CD.
A'
B1
Section AB.
1C
D
5 M.
0
10

tous limestone of indifferent consistence. The body of the masonry is in Fontaine rubble pugged with cement mortar; but the first course is in white Sassenage rubble squared and roughly faced.

Discharging arch. — The spandrels are connected by three rows of cross-vaulting, $1^{m},50$ in span and $0^{m},40$ in thickness, which support pillars $0^{m},80$ square.

Centre. — The bridge was constructed by means of a centre firmly fixed, composed of six ribs $1^{m},50$ apart from axis to axis, and resting on six supports in the river, of which the only one worthy of notice is a bottomless caisson sunk directly upon the gravel and filled with beton : the uprights and sides of the caisson were arranged so as slip between the ties and thus adapt themselves to the inequalities of the river bed.

The coffer-dam formed in this manner is surrounded by a course of stone-packing or enrockment, and has satisfactorily resisted the action of the torrent.

The construction of the centre was facilitated by a small railway, which, starting from the workshed, ran alongside the arches on the down-stream side of the bridge, and was laid upon the upright timbers supporting the centre.

Manner of constructing the arch. — The arch was built, between the 20th January and the 26th February 1874, in two superposed rings, the first of which has a thickness of 1 metre at the springer and $0^{m},50$ at the key. Each ring was subdivided into four blocks of equal bulk and

four gangs of men were employed at them simultaneously, part at the springers, part at the backs, and thus all were working together towards the key.

For a length of about $0^{m},80$ against the abutments, the courses from the springers were carefully laid without mortar, and on this temporary work the lower portions of the first ring were laid. The two upper portions were supported by madriers and chocks.

At the same time, the first two lower voussoirs were laid in ashlar and on chocks.

The closing of the ring at the key and at the haunches being accomplished, the dry stone-work was replaced by solid masonry, this operation being effected by means of underpinning.

The second ring was executed entirely in solid masonry.

This method of proceeding had the advantage of lessening the weight and the settlement of the centre, while it offered greater facility for the recommencement of the masonry. The simultaneous closing of the first ring at the springers and the key had the effect of securing the springing joints, which correspond with the joints of rupture, against the settlement of the centre, and thus fissures, that might have been impossible to close, were avoided.

Iron ties. — Seven iron ties, completely sunk in the masonry, connect the bandeaux which are in ashlar.

Composition of the mortar. — The mortar employed in the construction of the arch was composed of 1 litre of sand from the Drac to 1 kilogramme of Vicat's artificial

cement. At the expiration of a month the average resistance per square centimetre was, in round numbers, 179 kilogrammes crushing strain and 15 kilogrammes transverse. Subsequent experiments established a maximum of 260 kilogrammes crushing and 35 kilogrammes transverse strain. The mortar used for the spandrels and discharging arches contains 2 litres of Drac sand to 1 kilogramme of Vicat's cement.

Settlement of the centre. — The settlement of the centre did not exceed $0^{m},004$, and after the closing of the first ring of the arch it ceased entirely.

Striking of the centre. — The centre was struck on the 10th April 1874, or forty-two days after the completion of the arch. On the previous day, sand boxes had been substituted one by one for the blocks on which the centre rested. The striking was effected in twenty minutes. No rupture was discoverable in the arch, not a single joint opened, and there was no appreciable sinking at the key.

Pressures supported by the masonry. — The maximum pressure borne by the masonry of the arch is 21 kilogrammes per square centimetre at the key, while at the springers the total pressure is 3 100 000 kilogrammes along the whole breadth of the bridge, which is 8 metres between the heads.

Movements subsequent to the striking of the centre. — The variations of temperature have a very appreciable influence upon so large an arch as that of Claix

bridge. For a change of 52° in the temperature (from $-7°$ to $+45°$) an oscillation of $0^m,007$ at the top of the arch was observed. Some fissures have also been remarked in the joints of the coping, the plinth and the spandrels. These openings disappear in the summer, but become visible again during the winter.

The arch itself has suffered no deterioration, and no opening has been discovered in the joints of the springers.

Cost of construction. — The expenses of construction amounted to 139 563f,69.

This sum is divided as follows :

Dredging and excavating for foundations...		3 326f,78
Masonry of supports of centre.....		3 780 ,64
Framing of supports.....		5 562 ,33
Enrockments.....		1 600 ,56
Centre, properly so called.....		19 264 ,63
Masonry of the arch...	Rubble.....	45 435 ,40
	Ashlar.....	11 207 ,71
Spandrels, discharging arches, walls and beton for filling in.....		26 757 ,48
Bandeaux in dressed stone.....		15 208 ,35
Footways, gutters, stone-packing and approaches.....		8 419 ,87
TOTAL.....		139 563 ,69

In relation to the dimensions of the work, this sum may be divided as follows :

Span of arch per metre run.....	2 683f,91
Length by parapets per metre run.....	1 836 ,36
In plan between the springers per square metre.	331 ,35
In plan between the parapets.....	251 ,56
The centre cost per square metre of intrados.	68 ,15

The plans and specifications of the bridge were designed by M. Berthier, engineer in chief, and M. Pasqueau, engineer « des Ponts et Chaussées ». The works were executed under the direction of M. Gentil, engineer in chief, by M. Pasqueau till the 15th October 1873, and from that date by M. Cendre, engineer « des Ponts et Chaussées ».

M. Thiervoz, « conducteur », had the superintendence of the workshops.

MM. Muguet brothers were the contractors.

III

FOUNDATIONS OF COLLONGES BRIDGE,

ON THE RHÔNE.

COMPRESSED AIR CAISSON WITH AIR-CHAMBERS AND OPEN SHAFTS.

View of the bridge.

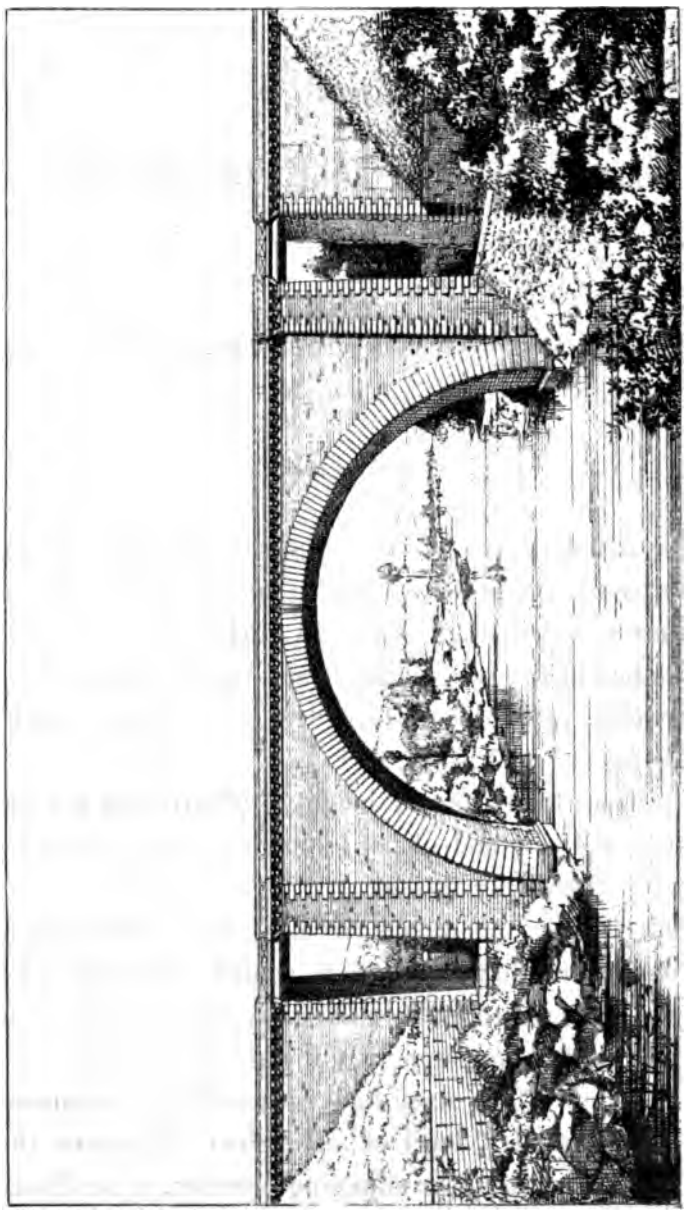
The national road N° 206 crosses the Rhône at the head of the pass between mount Vuache and mount Credo, at a distance of 800 metres above fort l'Écluse.

The bed of the river at this spot is much narrowed, and its breadth varies from 30 metres at low-water mark to 70 metres at high risings.

The river then attains a height of $7^{m},90$, and the water having a fall of 2 metres per kilometre, flows with a velocity of 5 metres per second.

Under these exceptional circumstances it was considered imperative that the current should meet with no obstruction whatsoever, and consequently that the bridge should be built without any support in the bed of the river.

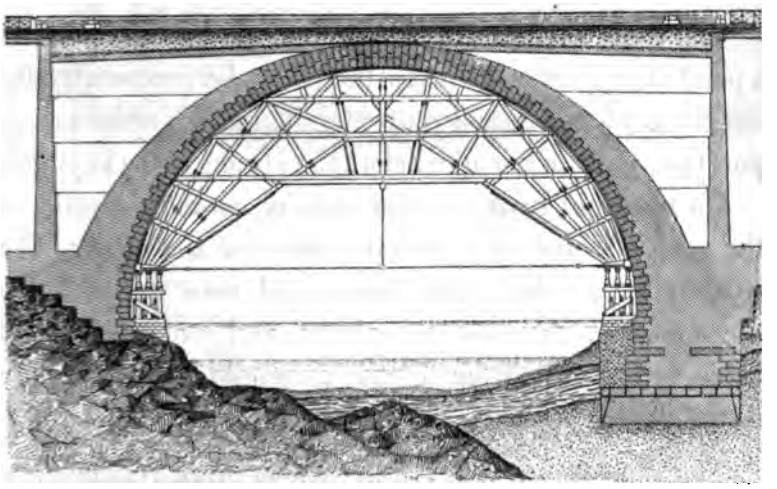
The nature of the steep banks permitted the roadway to be established at a level of more than 26 metres above low-water mark, and the adjoining quarries, of corallaceous oolite, afforded materials of excellent quality.



It was therefore decided to construct a single semicircular arch of stone, with a span of 40 metres. For purposes of military defence it was necessary to add two iron bays, and a ministerial order of the 17th May 1867 enjoined their construction.

The right bank abutment rests on a compact rock which is perfectly bare and projects from the bank.

On the left bank is a talus 28 metres in height, and at an angle of 45°.



The borings at the foot of this talus showed that the rock was too deep to be reached for the purpose of a foundation, and that this latter must be established upon ground possessing a certain power of resistance and incapable of being undermined or washed away.

Below low-water mark, layers were found successively of gravel mixed with sand, of pure sand, of large shingle cemented by clay, and a layer consisting of hard marl and

pebbles, forming a kind of pudding-stone, then a thin layer of loam with pockets of fine sand, and finally a deep mass of gravel commencing 4 or 5 metres below low-water mark.

To ensure the solidity of the left bank abutment of the arch of 40 metres, it was necessary to carry the stone-work down to 6 metres below the lowest water, or 14 metres below the great risings. At that depth, it would rest on a bed of pure gravel, and for the execution of this work it was decided on the 29th July 1869 to employ an iron caisson with compressed air.

The same reasons that militated against the adoption of a point of support in the bed of the river, also necessitated the employment of a cocked centre solidly laid, in order to support the weight of the arch before the placing of the keystone.

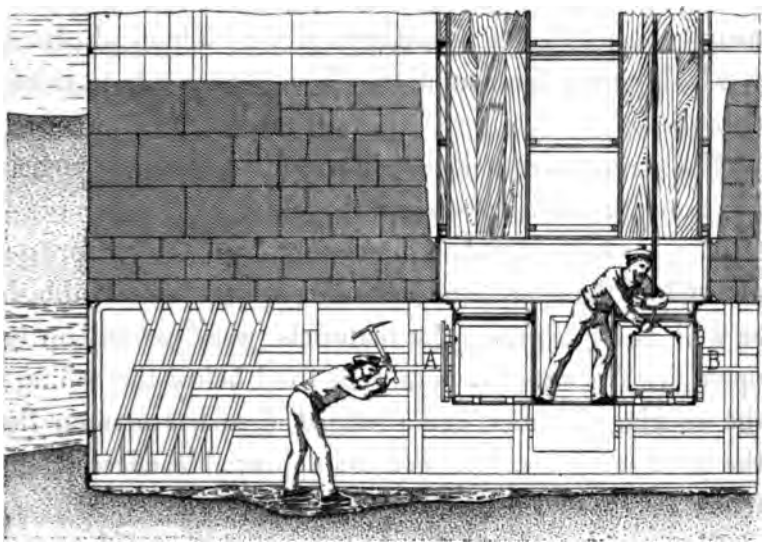
On the right bank, a solid mass of masonry resting on the rock afforded an immovable base for the centre. The support for the left bank was a solid mass founded like the abutment itself on the caisson, and consequently not liable to movement or to the undermining action of the water during the risings of the river.

The dimensions of the iron caisson were regulated in accordance with these conditions, and are as follows:

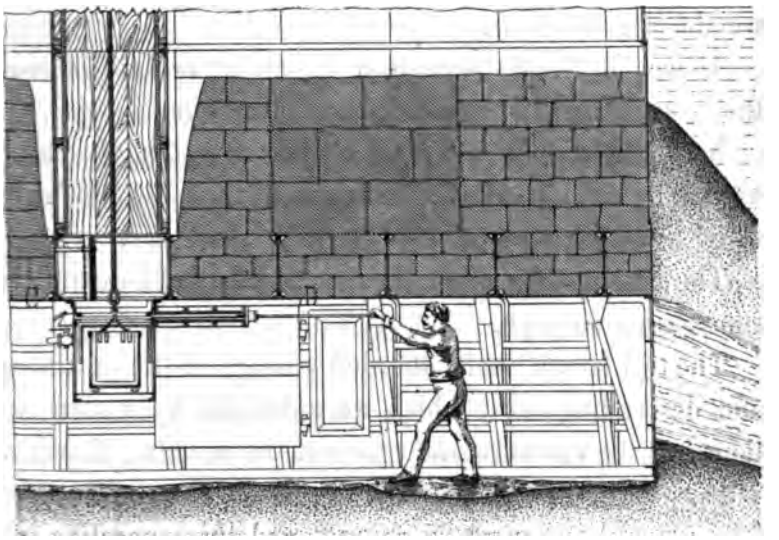
Length	$11^{m},50$
Breadth on the land side	10 ,00
Breadth on the Rhône side	7 ,50

The breadth of 10 metres commenced to diminish on the land side of caisson at $6^{m},20$.

The height under the ceiling in the working chamber was 2 metres.



Longitudinal half-section.



Transversal half-section.

The principal object of this paper is to explain the manner in which the foundation of the left bank abutment was laid, under the conditions which have just been briefly described.

The arrangements of the caisson differ in some particulars from those hitherto adopted :

The working chamber alone contained the compressed air, and all the operations for raising the excavated rubbish, as well as for lowering the materials, were carried on the open air. The air-chambers were fixed below the ceiling of the working chamber, and arranged in such a manner that the passage of the tubs had no appreciable effect on the tension of the air.

The working chamber was formed of strong sheet-iron $0^{m},009$, strengthened by cross-pieces, and the brackets supporting the ceiling enabled it to bear an additional weight of 1 500 tons.

Above, a simple sheet-iron casing or jacket, $0^{m},004$ thick, separated the masonry from the water.

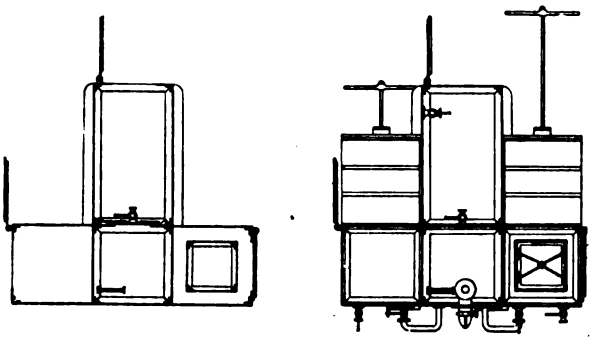
Near the middle of the ceiling was a rectangular shaft $2^{m},85$ by $1^{m},15$, divided into three open air shafts by three transversal partitions.

The central tube or shaft contained the ladders and the compressed air pipe.

The two lateral shafts afforded passage to the ascending and descending tubs, which were directed by a man stationed at the entrance and egress of the working chamber.

In entering or leaving, each tub passed through a coffer forming a chamber $0^{m},85$ square, and this operation was performed by means of a slide and a valve-door.

At the bottom of the central shaft, between the two coffers for the tubs, a landing-place was formed, on which a man stood to hook and unhook the tubs; the same man also regulated the working of the cocks. A vertical door, $0^m,50$ in breadth and $0^m,90$ high, afforded means of descent into a small chamber forming an air-sluice giving passage



Horizontal sections of the working chamber
after CD. after AB.

to the men, and opening by a second vertical door, $0^m,50$ by $1^m,40$, into the working chamber.

The floor of this air-chamber was only $0^m,40$ above the level of the excavations.

The sides of the shaft, having no pressure to support, were formed of sheet-iron $0^m,005$ to $0^m,007$, and were protected against the passage of the tubs by simple deal planks.

The whole apparatus of chambers and shafts was so arranged as to be capable of removal at the moment that the compressed air should cease to drive back the water, that is to say, as soon as the operation of sinking the caisson should be completed and the chamber filled in with masonry.

The arrangements here described offered the following advantages:

1° The number of workmen in the compressed air chamber is reduced to a minimum.

2° The men in the working chamber experienced a feeling of greater security, the means of egress being close at hand, and the communication with the workman at the bottom of the open air shaft, being perfectly easy.

3° The entrance or egress of the materials produced no appreciable change in the pressure.

4° The extent of surface that it was necessary to watch carefully, in order to guard against the escape of the compressed air, was reduced to the smallest dimensions.

5° The air-chamber being a fixture was the cause of much time being saved. Without any interruption of the work, and in proportion to the sinking of the caisson, the shaft could be lengthened, so that the top was always above the level of the risings of the river.

6° The cost of the work was singularly reduced by the substitution of thin sheet-iron in the rectangular shaft, in the place of iron which would have required to be sufficiently strong to resist the pressure of the compressed air, and finally very little air was lost in the passage of the tools and materials.

The results of the system described in this paper were most satisfactory. The caisson was sunk without accident to a depth of 6 metres below the low-water mark of the Rhône, or 8 or 9 metres below the average level of the water, and 12 or 14 metres below the great risings of the river.

The lowering of the caisson, the excavation and clearance

of the bottom, the sinking and the stone-work in the working chamber and upwards to low-water mark occupied two months and were completed on the 4th July 1870.

Sixty-three men were employed, of which number thirty-two were occupied in the working chamber and were divided into two gangs relieving each other every six hours. The excavations in the working chamber cost on an average 23f,50 per cubic metre.

The cost of the labour for the filling in masonry amounted to 16 francs per cubic metre. The entire foundation of the left bank abutment of Collonges bridge, to the level of low-water mark, was executed for a total sum of 80 000 francs[1].

The foundations were laid, under the direction of M. COLLET-MEYGRET, engineer in chief, by M. SADI CARNOT, engineer, who drew the plan of the system followed and superintended its execution.

The construction of the bridge itself was confided successively to MM. CARNOT and COURTOIS, engineers under the direction of M. COLLET-MEYGRET, engineer in chief.

The working arrangements were superintended by M. BIJON, conducteur, aided by MM. MILLET and MISTRAL, subordinate-assistants.

M. MASSON, the contractor for the works, assisted in the plans of M. CARNOT and carried out the new method of foundation.

M. GIRARD succeeded him in the contract for the construction of the work above low-water mark.

[1] This system of foundation was described in a more complete manner in the «*Annales des Travaux publics*» (N° 3, 10 March 1880).

IV

PORT-BOULET BRIDGE,

ON THE LOIRE.

(DEPARTMENT OF INDRE-ET-LOIRE.)

DEPARTMENTAL ROAD N° 11.

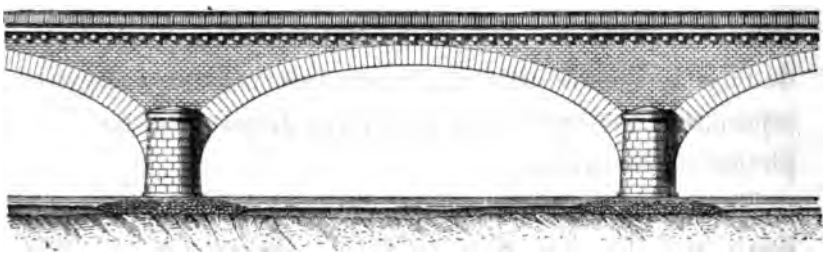
Statement. — Since the year 1837, the departmental road N° 11 from Chinon to Château-du-Loir was carried across the Loire by means of a suspension bridge at Port-Boulet.

This bridge suffered great damage in the last war and was completely destroyed a few months afterwards, while undergoing a test to which it was judged necessary to subject it.

In 1872, a plan for reconstructing it in stone was prepared by the engineers of the department, but the execution was deferred, there being at that time a question of making a railway of local importance between Port-de-Piles and Port-Boulet, and it was then considered that a single construction would meet the requirements of the departmental road N° 11 and of the railway.

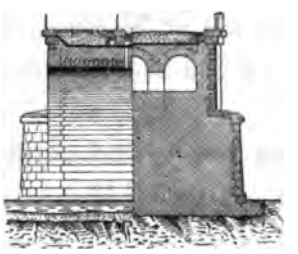
Various combinations were studied, and in the sessions of August and October 1873, the general council of the department adopted a plan for a railway and a road for vehicles. The estimate amounted to 1 450 000 francs, of which sum the council voted 920 000 francs and applied to the Government for a grant of the remaining 530 000 fr.

This combination was submitted to the heads of the administration and approved by a ministerial order of the 28th February 1874. The works were contracted for on the 2nd May 1874 and completed by the end of October 1876.

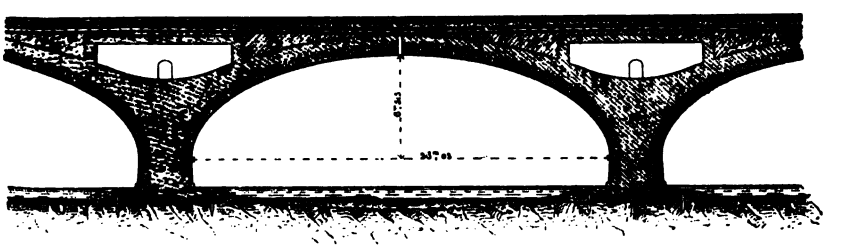


Elevation of an arch.

Transversal half-section of an arch.



Transversal half-section of a pier.



Longitudinal section.

Principal dimensions. — The bridge consists of sixteen stone arches, each having a span of 26 metres, in

form of an ellipse surbased to the quarter. The total length is 492^{m},80.

The breadth between the heads is 10^{m},40, but the corbelling of the parapets increases it in the clear to 10^{m},66, of which measurement 6^{m},20 are allotted to the departmental road N° 11, and 4^{m},40 to the railway from Port-de-Piles to Port-Boulet; 0^{m},06 are reserved for a fence of separation, the erection of which was deferred till the completion of the railway.

The springers of the arches are 1^{m},75 from low-water mark, and the rise being 6^{m},50, the height of the key at the intrados is 8^{m},25 above low-water mark, or 2 metres above the level of the rising of the river in 1856. The railway and the road are 2^{m},35 above the key in the intrados, that is to say, 10^{m},60 above low-water mark.

Principal dates of the undertaking. — The works were contracted for on the 2nd May 1874.

The foundations of the abutment on the left bank and nine piers were laid in the first season; the other six piers and the abutment on the right bank were constructed between April and September 1875.

While the foundations towards the right bank were being finished, the centres were raised and the arches commenced. The sixteen arches were completely finished in the course of 1875.

In 1876, the spandrels, discharging arches, and capping were constructed; the crowns of the piers were finished and the modillions, plinths and parapets laid, and on the 28th October 1876, less than thirty months after the

signing of the contracts, the bridge was opened to the public, notwithstanding a delay of three months occasioned by the formation of the road to the approaches.

Foundations. — The left bank abutment and the pier adjoining it were built dry, on the calcareous rock found at various depths in the bed of the Loire.

The other piers and the right bank abutment rest on the same rock, laid bare by dredging in enclosures of piles and sheet-piling. In the case of the five following piers, the rock was reached at depth of 1 and 2 metres below low-water mark, but beyond the sixth pier the rock dips abruptly, and from the seventh pier to the right bank abutment it only appears at depths varying from $5^{m},50$ to $7^{m},75$.

The foundations inside the piling are in beton; in the left bank abutment and the first pier, the beton was laid dry, but for all the other piers and the right bank abutment, it was submerged and levelled at $0^{m},20$ below low-water mark.

The piling is supported on the outside by enrockments which have been laid so as to correspond with the level of the beton submerged inside the enclosure.

The first courses of the piers, above the submerged beton, were laid by means of small cofferdams of beton formed on the solid mass and backed by the piling of the enclosure.

Nature of the materials. — The mortar was composed of five parts of powdered lime to nine of sand. The lime came from the calcareous beds of Paviers (kilns of Genève and C^{o}).

The submerged beton was made with two parts of mortar to three of broken shingle.

The up-stream and down-stream starlings, socle, cordons, pier crowns and head-bands of the arches are in Alençon granite. Pontlevoy and Champigny stone was originally intended to be employed for these different parts of the construction; but the contractor requested to be permitted to substitute granite, without alteration of the cost, and this modification was allowed.

The modillions, plinth, belting courses of the angles of the abutments and the parapets that surmount them are in ashlar from Valenay (Cher) and Chauvigny (near Poitiers).

The facings of the piers and arches are in rusticked rubble from Pontlevoy; the facings of the spandrels are in rusticked rubble from Bourgneuf (near Chinon), and the remainder of the masonry in rubble of the district.

The parapets above the arches are formed of cast-iron uprights connected by an iron head-rail.

Cost. — The estimate amounted to 1 450 000 francs, but in consequence of a reduction in the contract price, this sum was diminished to 1 437 514^{f},95.

The outlay corresponded to the previous estimate and is divided as follows :

Contract works.....	1 333 221^{f},09
Contingent expenses.....	104 293,86
TOTAL agreeing with estimate....	1 437 514,95

The length of the bridge being 492^{m},80, the net cost per

metre run is 2 736 francs, and the breadth of the bridge being $10^{m},40$ between the heads, the average cost per superficial metre of the superstructure is 263 francs.

But the cost per metre run must not be calculated in a uniform manner for the whole width of the superstructure. For a depth of 1 metre the cost of each head is evidently double that of a metre of the central zone or portion; and, to arrive at the average cost per superficial metre of the central portion, leaving out the two metres at the extremities, it is necessary to divide 2 736 not by $10^{m},40$, but by $12^{m},66$, which will give a quotient of 216 francs.

The surplus breadth allowed for the railway is 4 metres, and the corresponding cost per metre run is $4\times216=864$, which for the whole length of the work gives, in round numbers, 425 000 francs.

This outlay appertains to the railway.

The plans and specifications were prepared by M. Schérer, at that time engineer in chief of the department of Indre-et-Loire, and by M. de Basire, engineer.

The engineers to whom the execution of the work was entrusted were M. Viollet-Dubreil, engineer in chief of the department, who succeeded M. Schérer before the contracts were made, and M. de Basire, engineer.

The works were superintended by M. Gaillot, conductor « des Ponts et Chaussées. »

M. Genève was the contractor.

SECOND SECTION.

HYDRAULIC SERVICE.

V

THE PAS-DE-RIOT BARRAGE,

ON THE FURENS

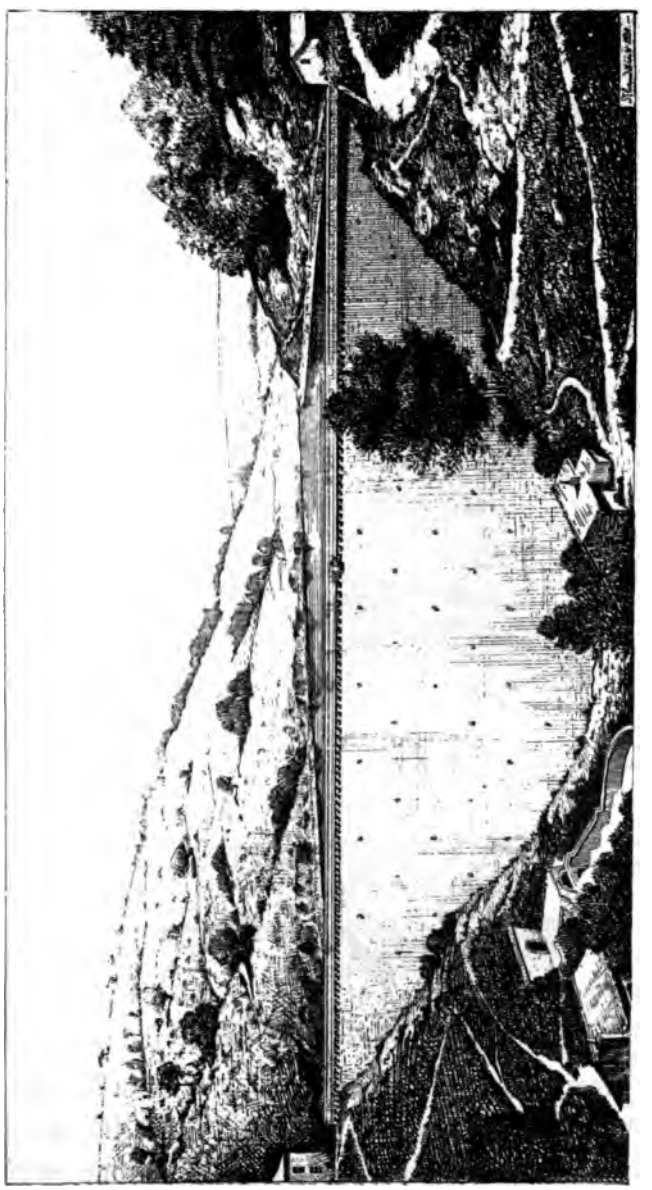
(DEPARTMENT OF THE LOIRE),

FOR THE SUPPLY OF WATER TO THE TOWN OF SAINT-ÉTIENNE.

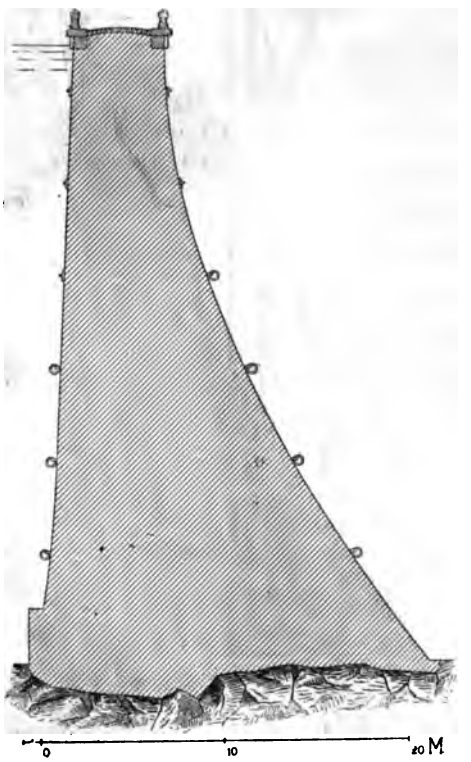
View of the barrage.

The town of Saint-Etienne formerly derived its supply of water from the springs which flow into the higher part of the valley of the Furens, or, in case of necessity, from the Gouffre-d'Enfer reservoir.

The waters of the Furens were collected at the Gouffre-d'Enfer. When the river discharged less than 300 litres per second, it was completely absorbed by the manufactories and the town received none; but when the discharge exceeded 300 litres, the town obtained the surplus. The quantity of water available for consumption was by no means adequate to the requirements of a town containing a popu-



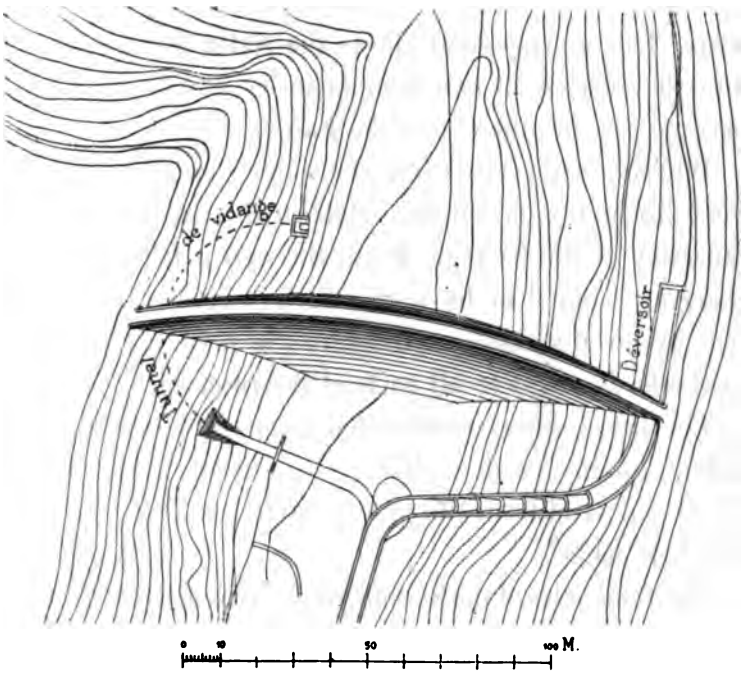
lation of more than 125 000 inhabitants. This state of things was considerably ameliorated by the construction of a new reservoir at the Pas-de-Riot, and by the acquisition of the waters of the river Furens itself, with the exception of a volume of water equal to 25 litres per second, which was reserved for the owners of property along the river-side.



The acquisition of the waters of the river Furens cost the town of Saint-Étienne 2 200 000 francs. It was made in accordance with the proposition of M. Lefort, engineer « des Ponts et Chaussées ».

The reservoir of the Pas-de-Riot was established at a distance of 2 200 metres above that of the Gouffre-d'Enfer.

The barrage of the Pas-de-Riot is capable of holding 1 350 000 cubic metres of water. It is 34^{m},50 in height, reckoning from the top of the causeway to the natural bottom of the valley. The thickness at the top is 4^{m},90 and at the level of the valley 21^{m},86.



The causeway of the barrage has an extent of 155 metres. In plan, it follows the arc of a circle with a mean radius of 350 metres.

The water of the reservoir is ordinarily distributed by means of an outlet tunnel 81^{m},10 in length between the heads, and formed in the rock against which the barrage

is constructed on the right bank of the Furens. The end of the tunnel, on the side of the reservoir, was closed by a solid mass of masonry 20 metres in thickness. In this block are laid two pipes $0^m,40$ in diameter, each fitted with an ordinary sluice-valve and a safety-cock. The pipes can replace each other. They discharge through the medium of a drain or deposit well, in order to deaden the shock of the water, into conduits in masonry which terminate in a distributing basin. This arrangement allows the water to be conducted into the reaches of two manufactories situated below the barrage, or into the bed of the Furens.

When the reservoir is full, the water runs off by a surface weir, 30 metres in length, established 1 metre below the causeway of the barrage. From the weir it falls into a discharging channel or by-wash which conducts it to the Furens by seven successive falls $3^m,50$ in breadth. A circular road affords access to all parts of the reservoir.

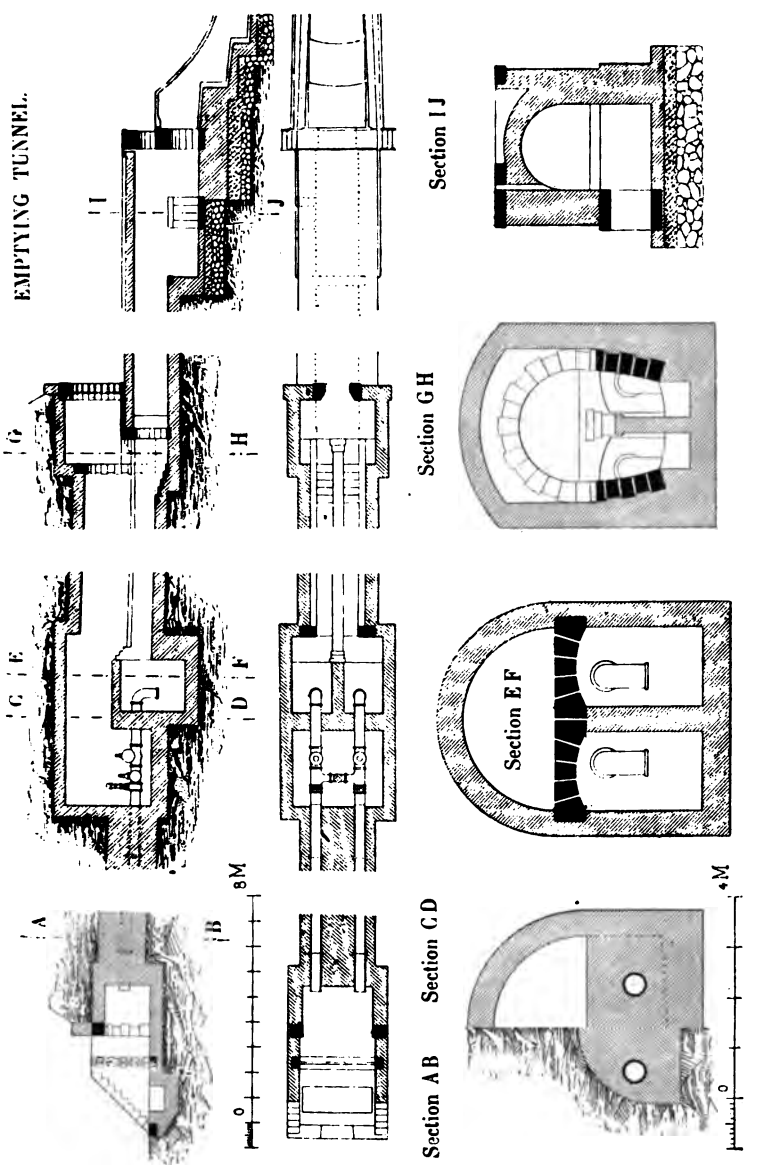
The barrage was constructed in granite rubble of excellent quality, with hydraulic lime from Theil (Lafarge kilns) and sand from the granite quarries. The crown is in Villebois ashlar.

The total cube of the masonry is 42,100 metres. The cube of the barrage masonry is 37 600 metres.

The entire cost including acquisition of ground, compensation and the works, amounted to 1 280 000 francs.

The cost per cubic metre of all the enclosed space is $0^f,95$.

The work was executed from 1873 to 1875 under the direction of M. Lagrange, engineer in chief; and from 1875 to 1878, by M. Jollois, his successor.


EMPTYING TUNNEL.
I
J
Section I J
G
H
Section G H
C
E
D
F
Section E F
A
B
8M
0
Section A B
Section C D
4M
0

The works were carried out under the immediate superintendence of M. Lefort, engineer.

M. Duplay, « conducteur des Ponts et Chaussées » was appointed to be constantly attached to the superintendence.

The contractor was M. Abougit.

VI

THE VERDON IRRIGATION CANAL.

(CHARTERED COMPANY.)

Chart of the canal.

The object of the Verdon canal is to irrigate the district of Aix and the surrounding country, to furnish the motive power for manufactories, and to supply water for drinking and domestic purposes. The concession was granted to the town of Aix by a decree of the 20th May 1863; the work was commenced by an English company under the title of «The French Irrigation Company», and finished by the «General Company of Canals and Public Works».

It consists of three divisions, the main or parent canal, the conductors or feed-canals and the channels of distribution.

1° **Main canal.** — The main canal is derived from the Verdon, one of the principal tributaries of the Durance, and has its origin at Quinson in the department of the Basses-Alpes. Its length is 82 075 metres and its discharge or delivery 6 cubic metres. The inclination varies from $0^{m},00019$ to $0^{m},00030$ per metre in the open parts, where the average section is 10,5 square metres, and $0^{m},0011$ in the underground channel, where the section is reduced to 4,78 square metres.

The most remarkable part of the canal is where it passes

through the mountain gorges of the Verdon, for a distance of 8 kilometres. Sometimes underground, sometimes supported by walls along a range of perpendicular rocks, it is only accessible by means of a narrow path cut in the rock, or formed of planks laid upon iron brackets. There are sixty-one underground passages for the canal, and their united length is 3 085 metres; chamber walls were built along 4 920 metres, and in the few parts where cuttings sufficed to form the channel, it was necessary to face them throughout with hydraulic masonry.

Outside the gorges, the Verdon canal required 20 underground passages, whith a total length of 16 236 metres; 3 aqueduct-bridges, 4 great syphons, 66 aqueducts, 13 bridges below, 95 passages above, and a length of 6 182 metres of wall for the steep banks.

2° **Conductors.** — The conductors or feed-canals are eight in number. The most important works connected with them are the Calèche aqueduct-bridge, 1 116 metres in length, on the branch on the left bank of the Touloubre, and the syphon of the Arc, with a development of 940 metres, on the conductor of the Milles. The number of works of smaller importance exceeds eight hundred.

3° **Channels of distribution.** — The Chartered Company has engaged to construct channels of distribution in the district of Aix. The length of the channels executed up to this date is 300 kilometres; the number of the works (bridges, syphons, falls, etc.) is about two thousand nine hundred.

4° **Irrigable perimeter.** — The extent of ground capable of being watered by the Verdon canal is 9 155 hectares in the district of Aix, and 8 790 hectares in the surrounding districts. The irrigable lands have a considerable slope and are almost destitute of water. The first year's operations resulted in the irrigation of 392 hectares; the principal cultures were meadow grass, lucerne, potatoes, kidney-beans and plants appertaining to market-gardens.

5° **Motive powers.** — The longitudinal section of the conductors or feed-canals is intersected by a number of falls which are intended to furnish motive power. The aggregate force of these falls is equal to 1 425 horse-power of 100 kilogrammetres, or 1 900 horse-power o steam, of which 660 are capable of being utilized at Aix alone. This motive power offers great advantages to the industrial interests of the community, in consequence of the regularity of the supply and the economy effected in dispensing with the employment of steam-power, and their proximity to a great centre of population places them in a most favourable situation.

Cost of construction. — The outlay attending the establishment of the Verdon canal amounts to 14 727 783 fr., exclusive of the interest of the capital employed, and it will be necessary to expend an additional sum of 700 000 francs for five conductors or feed-canals outside the district of Aix.

Description of the principal constructions. — Barrage of the head of water. — The head of water

is on the Verdon, a torrent river which rises in the Basses-Alpes, near Castellane, and runs into the Durance about 10 kilometres above the Mirabeau pass.

A gorge only 30 metres broad was selected for the site of the barrage.

The section of the masonry is in the form of a curvilinear trapezium, and the height above the plane of the foundations is $11^{m},33$; the breadth is $9^{m},91$ at the base and $4^{m},32$ at the top.

In plan, the barrage is constructed following an arc with a chord of 36 metres and a versed sine of $5^{m},80$. At each extremity it is built $1^{m},50$ to 2 metres into the solid rock.

The total height above the foundation rock exceeds 18 metres.

The outlet or discharging apparatus is continued in the solid rock on the left of the barrage, and consists of four semicircular openings, closed by sluice-valves and discharging into an underground culvert of about 70 metres in length.

The middle of the front of the barrage is occupied by a projecting fore-part of which the interior space extends through the rock to the bottom of the river, to the entrance of a lateral underground passage to the Verdon, and which allows part of the water to be let off. The breadth of this passage is divided perpendicularly to the channel by three openings each fitted with two sluice-paddles.

The barrage was commenced in the course of 1866, and after three seasons of severe toil, was completed in the first three months of 1869.

Principal underground works. — The most important underground passages of the Verdon canal are those of Maurras, Ginasservis, Pierrefiche, Rians and Saint-Hippolyte. That of Maurras extends to a length of 4126 metres and necessitated the construction of seven shafts, of which four are more than 100 metres in depth and one more than 200 metres. The underground passage of Genasservis is 5080 metres long, and the twelve shafts necessary to open it represent a total depth of 717 metres. That at Pierrefiche extends along 3029 metres, and those of Rians and Saint-Hippolyte are respectively 891 metres, and 950 metres long.

Aqueduct-bridges. — *Aqueduct-bridge of Beaurivet.* — The aqueduct-bridge of Beaurivet is $88^{m},67$ in length and 14 metres in height, measured between the coping or top of the chamber-walls and the bottom of the valley. It is formed of ten semicircular arches of 6 metres span. The breadth or trough of the channel on the aqueduct-bridge is $2^{m},61$, and of the work between the heads, $4^{m},21$.

Aqueduct-bridge of Malourie. — The aqueduct-bridge of Malourie is $31^{m},90$ in length and 16 metres in height from the bottom of the ravine which it crosses. It consists of three semicircular arches of 8 metres span. The breadth of the trough is $2^{m},60$ and of the bridge between the heads $4^{m},16$.

Aqueduct-bridge of Parouvier. — The aqueduct-bridge of Parouvier is $121^{m},30$ in length and $20^{m},75$ in height from the bottom of the valley to the coping of the chamber-walls. It consists of twelve semicircular arches of 8 metres span.

The breadth of the work is $4^{m},04$ between the heads, and of the trough $2^{m},50$.

Syphons. — *Trempasse syphon.* — The Trempasse syphon crosses a valley 132 metres in breadth at the level of the bottom of the canal and 27 metres deep below this level. It is formed by an underground gallery cut in the rock, and passing 12 metres below the natural water-course of the valley. The rock is faced with a casing in masonry which renders it perfectly impervious; the thickness of the thinnest part above the tunnel is 7 metres.

The circular section of the gallery is $2^{m},30$ in diameter, and it terminates at its extremities in two vertical shafts in masonry. The thickness of the revetment is from $0^{m},30$ to $0^{m},40$.

To ensure the clearing or emptying, it was necessary to retain, at the bottom of the valley, a vertical shaft, 14 metres deep, which was used in the construction, and which communicated with the syphon by a perpendicular gallery. To isolate this syphon shaft necessitated the construction, in the gallery of communication, of a barrage in ashlar traversed by a cast-iron tube which was joined to a pump placed at the bottom of the shaft and worked by means of a winch with crank-shafts.

The expenses attending the execution of the work amounted to 60 000 francs, or 454 francs per metre run, viz:

Sinking and tunnelling of shafts and galleries..	29 000[f]
Masonry of revetment, heads of syphon and barrage.....	26 000
Accessory works and emptying apparatus.....	5 000

La Lauvière syphon. — The La Lauvière syphon traverses a valley of which the sides are composed alternately of a very compact pudding-stone and a hard sandstone, while the bottom is covered with a thick bed of clay. The nature of the ground compelled the adoption of a mixed plan. Underground galleries, similar to those constituting the syphon at Trempasse, were excavated in the hard rock, and the central part was formed of an iron tube resting on blocks of squared stone.

The length of the entire work, measured from axis to axis of the shafts terminating the underground galleries, is $272^{m},70$, and the maximum rise $23^{m},50$. The galleries are $2^{m},30$ in diameter, and their slope varies from $0^{m},06$ to $0^{m},19$ per metre. The length of the up-stream gallery is $105^{m},30$, and that of the down-stream gallery $47^{m},50$.

The iron tube is 120 metres in length and $2^{m},30$ in diameter; its thickness is $0^{m},01$. It is formed of sheets joined in their length and breadth by clinker riveting with a single row of rivets. The supports, by means of which it rests on the stone-work, are of cast iron; they are twenty-three in number, and are set on movable cast-iron rollers. At each end is placed a dilating apparatus, formed of hammered iron, and fitted with a demi-torus connected with the tube by plane faces and susceptible of a kind of bellows movement. The great diameter of the torus is $3^{m},86$ and that of the generating circle $0^{m},54$. The emptying is accomplished by means of a sluice-cock $0^{m},50$ in diameter. The junction with the underground galleries is effected by cast-iron rings embedded in the masonry.

The expenses attending the construction of the La Lau-

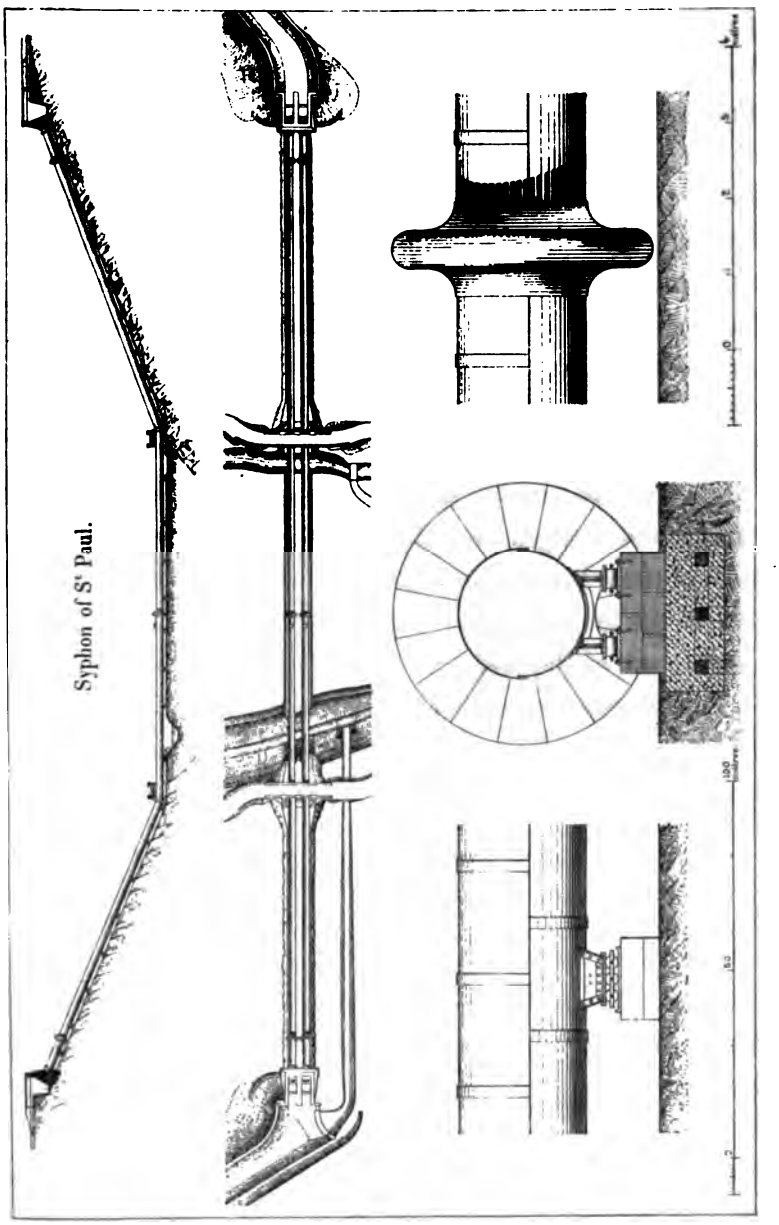
vière syphon amounted to 180 000 francs, or 660 francs per metre run; they are divided as follows:

Sinking and tunnelling of shafts and galleries..	27 150[f]
Masonry of revetment and of the heads.....	65 500
Iron part.....	87 350

Saint-Paul syphon. — This syphon was formed to traverse a valley 293 metres in breadth and 36[m],15 in depth below the level of the canal. It consists of two iron tubes, 1[m],75 in diameter, established parallel to each other at a distance of 4 metres from axis to axis, and in a direction perpendicular to the valley. Each tube consists of a horizontal part 98[m],06 in length, contained between two sloping parts 76[m],49 and 84[m],01 in length. The slope of the up-stream part is 0[m],41 per metre, and that of the down-stream part 0[m],39 per metre. At each angle is a support formed of an iron chair resting on a solid mass of ashlar. In the same manner the other supports rest, by the aid of rollers, on blocks of ashlar masonry. The length of the up-stream bays is 10[m],80, and of the down-stream bays 10[m],40; of the central part near the angles 12[m],50, and of the intermediate parts 10[m],45; this difference was caused by two brooks, each of which it was necessary to cross by a single span.

The straight parts of the syphon are fitted with bellows-shaped dilating apparatus, similar to those of the La Lauvière syphon. Sluice-cocks 0[m],30 in diameter are also placed at the lowest point in order to let off all the water.

At each end, the tubes terminate in independent drain-wells, of a rectangular form, the up-stream well being 6[m],72


Syphon of S^t Paul.

in depth and the down-stream well $6^{m},61$. Channels cut in the chamber-walls at the head of the wells allow either half of the syphon to be emptied in case of need, without interfering with the working of the other.

The tubes are composed of sheets of iron $0^{m},008$ in minimum thickness with clinker-joints in the longitudinal and lapping-joints in the transversal direction; the longitudinal joints have a double riveting, and the transversal a single riveting. The elbows or angles joining the sloping to the horizontal parts are in hammered iron, fastened to each other and to the next sheets by outer lapping-joints with double riveting.

The syphon crosses two roads and it was necessary to build stone bridges over them. Against the abutments and piers of these bridges are fixed iron ears, placed at the bottom of the sloping tubes, and which prevent their sinking on account of the weight.

The expenses attending the construction of the Saint-Paul syphon amounted to $254\,388^{f},95$, or 937 francs per metre run; this sum is divided as follows:

Earthwork and masonry	$63\,206^{f},88$
Iron part	181 712 25
Sundries	2 835 10

Aqueduct-bridge of Calèche. — The Calèche aqueduct-bridge on the conductor, called « the left bank of the Touloubre », extends over a length of $1\,165^{m},65$ and presents a maximum height of $9^{m},16$. It consists of one hundred and forty-six semicircular arches of 6 metres span and an iron trough 20 metres long for the crossing of

the national road N° 96. Nine abutment-piers, strengthened by counterforts, divide the work into twelve sections consisting of fourteen arches for that part of the aqueduct-bridge situated on the up-stream side of the national road, and thirteen arches for the down-stream side. The breadth of the trough is $0^{m},66$ and the depth $0^{m},90$. The slope of the ground being very gradual, the abutments are of great length and are hollowed out by five small arches on the up-stream and eight on the down-stream side.

In plan, the outline is not rectilinear, since it follows the crest of the ridge to be crossed, in such a manner as to diminish the height of the loftiest piers and to traverse the national road at an angle of less than 50°.

The bridge was built of ordinary stone-work throughout; the facings of the piers and arches are in coursed rubble; those of the spandrels are laid in uncoursed rubble.

The total cost, including the setting of the iron trough, was 158 500 francs, or 142 francs per metre run.

All the works described in this notice are due to M. de Tournadre, engineer « des Ponts et Chaussées »; M. Bricka, engineer « des Ponts et Chaussées », finished the Verdon canal and built the Calèche aqueduct.

The engineers who particularly assisted in the plans and execution of the work, were MM. Berger, conducteur « des Ponts et Chaussées »; Lasvigne, civil engineer; Ernout, chief draughtsman; Wachowski, chief engineer of the Verdon canal section; and Guillaume, chief of the service of the conductors or feed-canals. The iron part of the Saint-Paul syphon was laid by MM. Lejeune and Ménard, contractors.

VII

THE LAKE OF ORÉDON RÉSERVOIR

AND THE DISTRIBUTION OF THE WATERS OF THE NESTE.

(DEPARTMENT OF THE HAUTES-PYRÉNÉES.)

View of the barrage.

Object of the distribution of the waters of the Neste. — The distribution of the waters of the Neste was undertaken with a view to the agricultural improvement of the numerous valleys at the foot of the Pyrénées, and which commence at the plateau of Lannemezan. This region includes all the department of Gers and a portion of the departments of the Hautes-Pyrénées, the Haute-Garonne, Tarn-et-Garonne and Lot-et-Garonne. During the summer, throughout this extent of country, the rivers are nearly dry, the mills are idle, and the inhabitants suffer from the scarcity of water for their cattle and for the most ordinary requirements of life.

The Neste canal. — The problem was in some measure solved by conveying part of the Neste water to the plateau of Lannemezan by means of a canal 28 kilometres in length, of which the head of water is at Sarrancolin. It is capable of discharging 7 cubic metres per second, and with this quantity it waters a great part of the plateau of

the landes of Lannemezan and supplies the valleys and rivers of the Louge, the Save, the Gesse, the Gimone, the Arrats, the Gers, the Baysolle and the three branches of the Baise and the Bouès.

As the abstraction of 7 cubic metres per second, from the Neste, when the water is low, could not be effected without infringing vested interests, it was necessary to resort to the construction of a reservoir at the lake of Orédon.

Situation of the lake of Orédon. — The lake of Oredon is situated near the water-shed of the basins of the Neste and the gave or mountain stream of Pau; it is nearly on the axis of the Pyrenean upheaval, and the geological development of the district is entirely granitic. It has for tributaries, four lakes, viz. Cap-de-Long, the Laquettes, Aubert and Aumar; and in addition, the two glaciers of Néouvieil and the Pic-Long. The superficies of its basin is 2770 hectares, and the level of low-water mark 1852 metres above the sea. The summits of the mountains surrounding it are more than 3 000 metres high, and are covered with snow for three quarters of the year.

The transformation of the lake of Orédon into a reservoir comprises the following works :

1° The opening of a channel or cutting in the natural weir or fall, and carrying it into the lake 7 metres below the water-level;

2° The construction of a barrage across the weir, which will enable the reserve to be raised to $16^{m},80$.

The reservoir is capable of containing 7 500 000 cubic metres.

Cutting. — The cutting made in the natural weir of the lake has a maximum depth of 7 metres and a length of 480 metres, 167 metres of which are in the lake and 313 metres in the weir itself; it is excavated in the solid granite.

To facilitate the work in the cutting, a causeway of earth, $3^{m},50$ above the level of the lake, was made at the commencement of the weir. At the end on the right bank, where the causeway meets the rock, an outlet drain 3 metres in breadth and closed with sliding beams, allowed the water of the lake to be retained or let off at discretion.

After the blasts were fired, and especially in the evening, the drain was opened, and a powerful stream of water, rushing out at a speed of more than 5 metres per second, made a complete clearance of every thing and swept the greater part of the blocks of stone thrown out by the blasts down to the cascade that terminates the cutting.

Hydraulic apparatus for the head of water. — The arrangements for the diversion and distribution of the water consist of eleven cast-iron conduit-pipes $0^{m},30$ in diameter, and terminating below by sluice-cocks of the same dimensions, made after the pattern of those used in the Paris water-works. On the higher or up-stream side, each conduit is fitted at the end with a widened or bell-shaped pipe $0^{m},60$ in diameter.

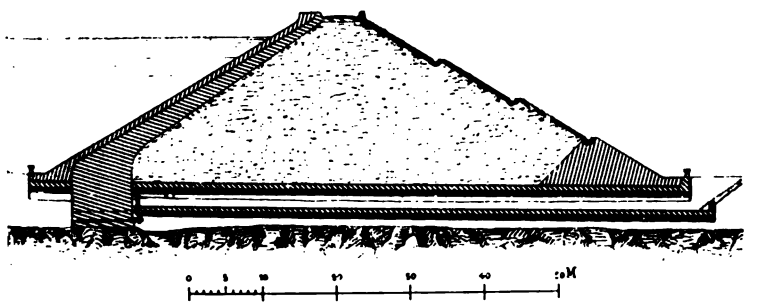
Below, the conduits are set in a solid mass of Portland cement 8 metres in thickness and 7 metres in height. They are arranged in two rows, five in the lower and six in the upper row.

The sluice-cocks are accessible below by means of a pas-

sage formed above the aqueduct, arched in the same manner, and bearing, along the whole length, the weight of the barrage.

Barrage. — Essentially, the barrage consists of an embankment, faced on the up-stream talus with beton-work, which is secured against the frost by dry stone-packing 1 metre in thickness.

Formation of the embankment. — The level of the embankment was prepared by clearing away the trees, brushwood, and all mould or vegetative soil.



Excavations were made underneath the masses of rock too heavy to be removed, and the solid rock was laid bare throughout, after which the important work of the embankment was fairly commenced.

The materials for the embankment were brought from the Prade de Camou, and a railway connected this spot with the top of the barrage. This railway consists of two lines which form a complete circuit; the upper, or arrival line, descends by a slope of $0^{m},010$ to $0^{m},011$ from the place

where the materials are obtained to the highest point of the barrage. The return line starts from this last point and goes by an inverse slope to the Prade de Camou, where it arrives at a level of 7 metres below the starting point of the upper line. This difference of level is made good by an inclined plane, up which an endless chain, moved by an hydraulic wheel, raises the trucks employed in carrying the materials. The slopes of the lines are so graduated that a truck, once started, continues to descend with moderate speed, either from the site of the materials to the barrage, or from the barrage to the bottom of the inclined plane. Each truck is fitted with a brake which the conductor can use, in case of necessity, to regulate the speed.

Method of forming the embankment by means of water. — Water was the principal agent employed in laying the foundation of the embankment, and this was effected in the following manner.

A stream of water was made to run at the rate of about 15 litres per second, in the ditch alongside the upper line of rails, and this water proceeded from the canal which put in motion the hydraulic wheel employed in drawing the empty trucks up the inclined plane.

Arrived at the barrage, the water could at discretion be discharged into a wooden conduit $0^{m},16$ by $0^{m},22$ fixed $0^{m},80$ below the rails on which the loaded trucks arrived. This conduit was lengthened according to the progress of the embankment, and it discharged at the point where each truck was tipped and emptied.

Two and sometimes three trucks were emptied, and the

end of the conduit was thus covered with $3^{cm},500$ to 5 cubic metres of earth; the water was then turned on, and the conduit, fixed with a slope of $0^{m},005$ per metre and having its lower end blocked up, filled rapidly. The mass of earth, permeated by the water, passed into a lava-like consistence more or less thick; then the water, making its way through, precipitated, with a deafening crash, earth, sand, broken stone and blocks down to the base of the embankment.

A gang of four or five men, provided with iron hooks, shifted the stones and guided the current to the right, left, or in front, as occasion required, in such a manner that a parallel was preserved between the upper and lower talus.

The water at the foot of the embankment, after depositing in its course the solid materials that it brought with it, flowed away to the right or left in the cutting, holding in suspension only light soil and fine sand in a state af mud.

In a few minutes, the materials deposited by the water, and in fact partly under water, were freed from the liquid which had served them as a vehicle. The sand lodged itself in the smallest interstices left by fragments of larger dimensions, no empty spaces were visible, and the entire mass presented a solidity which precluded the idea of any further settlement or sinking.

Revetment in beton. — The revetment was formed of beton with the view of preventing the infiltration of the water through the embankment, and of thereby effectually securing its solidity.

But however compact the beton-work may be, and whatever water-resisting properties may be possessed by the

excellent Theil lime which enters largely into its composition, the revetment will nevertheless, be found permeable, and in this particular it does not differ from all other masonry. Fissures caused by the shrinking of the mortar, or by the settling of the embankment or the beton, will make their appearance and afford an entrance for the water to penetrate. A course of bitumen was laid with the view of obviating this contingency.

But even this precaution is insufficient, since the cap may crack in different places, owing to the enormous pressure to which the up-stream talus is subjected, and consequently the destructive action of the water is still to be apprehended.

System of drainage. — Strenuous efforts were made to modify the danger above-mentioned, by interposing a general system of drainage between the embankment and the revetment.

The stone-packing which forms the up-stream talus is covered with a layer of beton $0^{m},20$ thick. On this layer is built a dry wall or stone-packing of a uniform thickness of $0^{m},30$, which forms the drain. And on this last stone-packing is laid the beton revetment with its bituminous facing.

At the foot of the talus, to the right and left of the solid mass containing the conduits, a collecting drain is formed at the base of the beton revetment, and communicates with the general drainage by means of outlets or barbacanes at intervals of 2 metres. The position of the outlets is marked on the exterior; and by this method a fissure in the principal revetment can be discovered by ascending it

and following the line of slope which terminates at the outlet from which the water escapes.

The collecting drains discharge their water into the passage which gives access to the sluice-cocks, and thence into the lower aqueduct.

They rise from the right and left up to the top of the barrage, where they pass under the crown and terminate on the lower talus of the embankment. They have a breadth of 1 metre and a height of $1^{m},50$ under the key, and a man can pass along them without difficulty; the bottom or floor is formed by the bare rock.

The collecting drains, still in an unfinished state have rendered important service during the construction of the work, by supplying means of discharge otherwise insufficient.

Construction of the beton revetment. — The sand and gravel required for the beton come from the Prade de Camou, as also the materials for the embankment. They are washed on the spot in running water and then measured and stored.

The mixture of sand and gravel is loaded on trucks, carried to the barrage and there deposited on platforms arranged beside the rails, and on which the beton is made. For this new service, trucks are used which tip from the side instead of the fore-part.

In one of the angles of each platform a hole $0^{m},30$ square, is formed, to which is fixed a vertical box made of boards $2^{m},50$ in height, in which are ranged horizontal iron rods in steps $0^{m},25$ apart and crossing each other in different directions.

This apparatus constitutes a beton-mill (bétonnière). The beton-mills are placed at an average distance of 16 metres from each other.

The lime is slaked on the platform. The water necessary for this operation is obtained from wooden troughs placed between the two lines of rails. All these troughs are kept constantly full by a wooden conduit $0^m,05$ in height by $0^m,10$ in breadth, connected with the lateral drain near the arrival line, and the surplus water is discharged from the last trough on the lower talus of the embankment.

The lime being made into a paste, is then spread on a measured quantity of sand and gravel about $0^m,15$ thick. A few turns of the shovel are given, to commence the mixture, and it is then thrown into the beton-mill, where the mixture is completed.

The beton made in this manner, falls into a shoot made of planks, the slope of which is the same as that of the talus of the embankment.

The shoot is $0^m,20$ broad, and to facilitate the passage of the beton, the bottom is lined with zinc plates. The beton forms in it a layer of from $0^m,06$ to $0^m,10$ in thickness, which slides slowly down at the rate of from $0^m,05$ to $0^m,10$ per second. From the lower end of the shoot it falls into a trough from which it is taken as required.

In the downward movement of the beton, the small stones often disengage themselves from the mass, and in rolling and bounding to the bottom, might injure the workmen at the lower end of the shoot. To obviate this danger, small swinging planks are suspended inside the shoot, nearly $3^m,50$ apart; they touch neither the sides nor the bottom,

while they receive the shock of the small stones and lessen the rapidity of their descent.

Weir. — The surplus water of the reservoir will flow off by means of a weir 40 metres in length, cut in the granite to the right of the barrage. In great risings when the reservoir is full, a sheet of water $0^{m},50$ in thickness will pass over the weir, this volume being equal to a discharge of 25 cubic metres per second.

Cost. — The works are estimated at 908 000 francs; they were not contracted for, but are executed under government inspection.

A large saving will be effected on the first estimates; the price per cubic metre of water will amount to about $0^{f},10$.

The first surveys were made by the late M. MONTET, engineer in chief, and date from the year 1840.

With regard to the definitive plans and the direction of the works, M. MICHELIER, engineer in chief, was assisted from 1867 to 1873 by M. D'USSEL, engineer, then by M. LIX, engineer, whose premature death in December 1875 was doubtless hastened by the fatigues to which he fearlessly exposed himself; finally M. ALVIN, engineer, succeeded M. LIX in July 1876.

VIII

SANITARY WORKS

AND IMPROVEMENT OF THE LANDES OF GASCONY.

(DEPARTMENTS OF THE GIRONDE AND THE LANDES.)

Chart on a scale of $\frac{1}{80000}$.

Preliminary statement. — The district known under the general appellation of « Landes », is comprised between the sea and the valleys of the Garonne and Adour. Its superficies is about 8 000 square kilometres, and until twenty-five years ago, almost the whole of this extent of ground was uncultivated and uninhabited. Far and wide the eye only perceived some isolated cottages and a few clumps of pines, and these were inaccessible during the winter in consequence of the inundation of the surrounding districts.

For a long period, numerous attempts had been made with the view of rendering this species of desert productive, but all had failed owing to the insalubrity of the country and the sterility of the soil.

At length, in 1849, after several years of careful examination, it was ascertained that all these marshy lands might be rendered healthy by works of a very simple nature, which would impart to them extraordinary fertility, and at a tri-

fling cost, would enable them to be put immediately into forest cultivation.

The results of the first experiments were recognized so conclusive that on the 19th of June 1857 a bill was passed for the sanitary amelioration and practical improvement of all the communal « Landes » of the two departments of the Gironde and the Landes, which constitute the most considerable portion of the uncultivated and unwholesome territory.

The works executed in consequence of this bill will be found indicated in the chart exhibited.

General description. Object and utility of the works. — The Landes constitute a vast plateau or tableland almost horizontal; the surface consists of poor and sandy ground $0^{m},60$ in depth, which presents no trace of clay or limestone, and rests on a subsoil perfectly impervious.

No spring or sign of water can be discovered during the summer; while on the other hand, for more than six months of winter, the plateau is visited by the frequent and copious rains which prevail near the sea; and as there exists no outfall for the water to run off, and the soil possesses little or no power of absorption, stagnant and noisome pools are formed and remain until evaporated by the heat. Thus, continuous inundation in the winter, and absolute drought of a burning sand in the summer, are the principal characteristics of the district.

Let us now picture to ourselves the effects of this annual transition from the six months' inundation in winter to the

long summer's drought succeeding it, and we shall arrive at some conception of the barrenness of the soil and the unhealthy nature of the country previous to the commencement of works of a sanitary character.

Description of the works. — In the Gironde, the improvements effected by the engineers have extended to fifty-two communes or parishes, and comprise a total of 107 811 hectares.

In the department of the Landes, the number of communes is one hundred and ten, and the surface 183 714 hectares.

Total for one hundred and sixty-two parishes, 291 525 hectares.

A larger surface has been drained and sown by the landlords.

The works executed by the government, for the communal landes comprise, in the Gironde, a length of 1 086 kilometres for outfall drainage, and in the department of the Landes a length of 1111 kilometres.

Total for the two departments, 2197 kilometres.

The canals follow the most sloping line of the plateau and have an average breadth of from 5 to 6 metres at the bottom and an incline of from $0^{m},002$ to $0^{m},001$ per metre.

A part of the landes of the Gironde is situated on the slope of the seaside, and the drainage is stopped by the chain of sand-hills which extends along the coast for 120 kilometres without interruption; it was therefore necessary to form a collector or drainage well 12 metres broad at the

bottom connecting the pools formed at the sand-hills, and affording an outlet for all the water of the slope.

Date and duration of the works. — The sanitary improvements of the communal landes of the Gironde were commenced in 1858 and completed in 1865. Those of the department of the Landes were commenced at the same date and finished in 1877, with the exception of 269 hectares which still remained to be improved in 1878.

Cost and results. — The total outlay amounted to 574 108 francs, for the Gironde, and 319 362 francs for the Landes.

Total, 893 470 francs.

From the abstract, it follows that the value of the communal lands in cultivation at the commencement of 1877, was for the Gironde, 30 955 700 francs, and for the department of the Landes, 49 308 900 francs.

Total for the two departments, 80 264 600 francs.

Independently of this area, an extent of 350 000 hectares of landes belonging to private owners was put in cultivation, and on the 1st January 1877, it represented a value of 125 millions.

Total of the actual value of the lands put in cultivation, 205 264 600 francs.

In consequence of the increase in the value of the land, owing to the improvements, the communes were in a position to sell part of their landes, and with the proceeds, to carry out projects of which it is sufficient to mention :

Building and restoration of churches, presbyteries or

parsonages, mayoralty-houses and schools; sinking of wells for drinkable water; removal of cemeteries; special grants for neighbouring roads, etc., representing altogether a sum of 7 503 915 francs.

These figures afford some grounds for judging of the moral and intellectual progress developed in these districts.

From a sanitary point of view the results are not less encouraging.

The fevers that devastated the country have entirely disappeared, and official investigations have established the fact that this district formerly so unhealthy may, at the present time, be considered one of the most salubrious in France.

The communes have paid for all the works of improvement and cultivation as also for the ameliorations before mentioned, without any assistance from the State, or the department; not only have the proceeds of their landes covered all expenses, but they have invested a sum of 4 352 746 francs in the government funds. Before the act of 1857, the district of the landes of Gascony was one of the poorest in France. To day it is one of the richest and most prosperous.

The sanitary works and improvement of the landes of the Gironde were commenced under the direction of MM. Malaure, engineer in chief, and Chambrelent, engineer, and finished under direction of M. Chambrelent, engineer in chief, and M. Lemoyne, engineer. The works were superintended by M. Courbet, conducteur « des Ponts et Chaussées ».

In the department of the Landes, the works were com-

menced under the direction of MM. Pairier, engineer in chief, and Crouzet, engineer. They were continued by MM. Crouzet, engineer in chief, Aubé and Salles, engineers, and finished under the direction of MM. Perreau, engineer in chief, Aubé, engineer, and Rodrigues, principal conducteur, acting as an engineer « des Ponts et Chaussées ».

THIRD SECTION.

INTERNAL NAVIGATION.

IX

EASTERN CANAL.

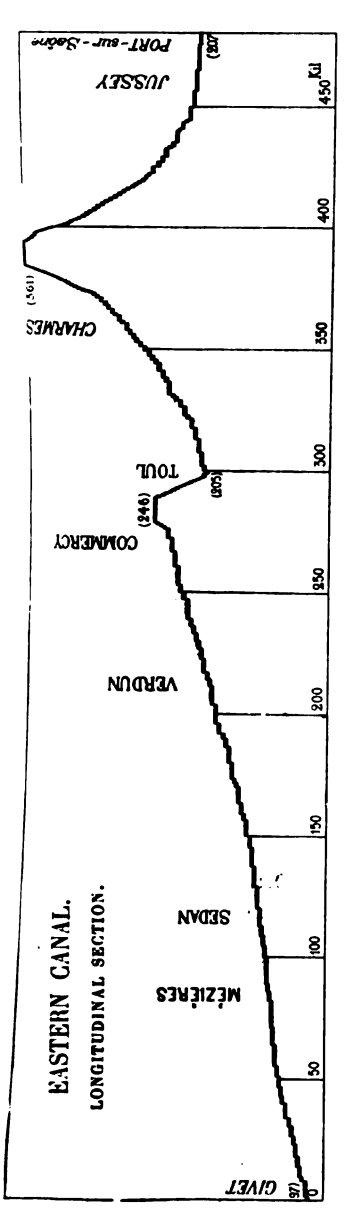
(ARDENNES, MEUSE, MEURTHE-ET-MOSELLE, VOSGES AND HAUTE-SAÔNE.)

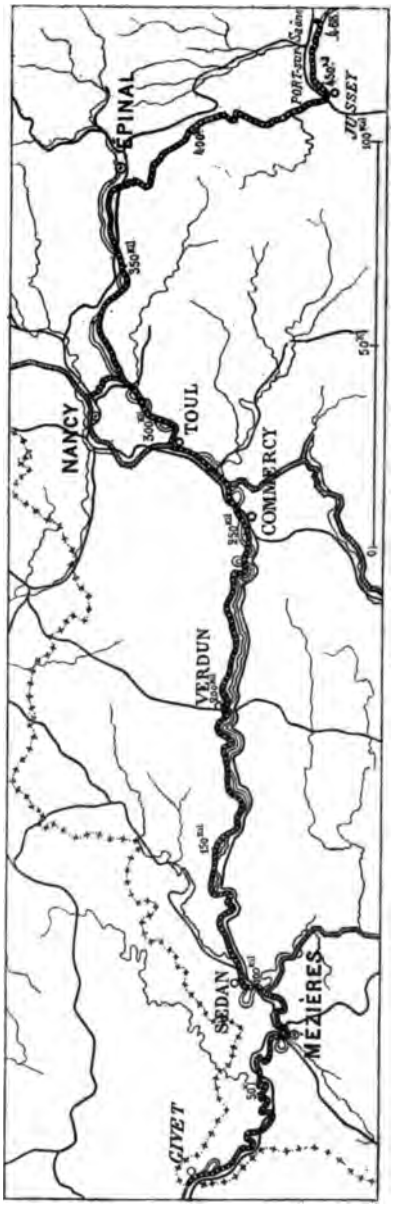
Set of drawings; chart and longitudinal section.

Statement. — The Eastern canal restores the connection of navigable ways intercepted on the French territory by the new frontier, and affords communication between the North, East and South of France.

The opening of this new way was authorized by an act passed on the 24th March 1874. Near Givet, at the boundary of the Ardennes department and Belgium, it joins the Belgian Meuse, the improvements of which are in course of execution and may be considered as completed.

The line passes up the valley of the Meuse as far as the point where the latter is crossed near Sorcy by the Marne and Rhine canal. It adopts this canal for a distance of 27 kilometres, till it reaches Toul; it then goes up the valley of the Moselle to a spot near Epinal, crosses the Vosges without a tunnel, again descends, keeping beside the Coney,


EASTERN CANAL.
LONGITUDINAL SECTION.
GIVET
MÉZIÈRES
SEDAN
VERDUN
COMMERCY
TOUL
CHARMES
JUSSEY
PORT-sur-Saône
0
50
100
150
200
250
300
350
400
450
Kl.
971
(1011)
(946)
(1207)


GIVET
MEZIERES
SEDAN
VERDUN
COMMERCY
TOUL
NANCY
EPINAL
JUSSEY

and lastly it adopts the canalized channel of the Saône and discharges at Port-sur-Saône.

The distance traversed from Givet to Port-sur-Saône is about 480 kilometres.

Two branches are yet to be constructed; one between Messein and Laneuveville, the other between Golbey and Epinal, and these works will augment the total length to about 500 kilometres. The former of these will connect the valleys of the Moselle and the Meurthe.

Beyond Port-sur-Saône, the necessary works have been commenced for the purpose of improving the Saône, so that it may be capable of receiving the canal-boats of the new navigable way, and these works are to be finished simultaneously with those of the Eastern canal.

In this manner, the Meuse, the Saône and the Rhône will afford uninterrupted communication between the North Sea and the Mediterranean.

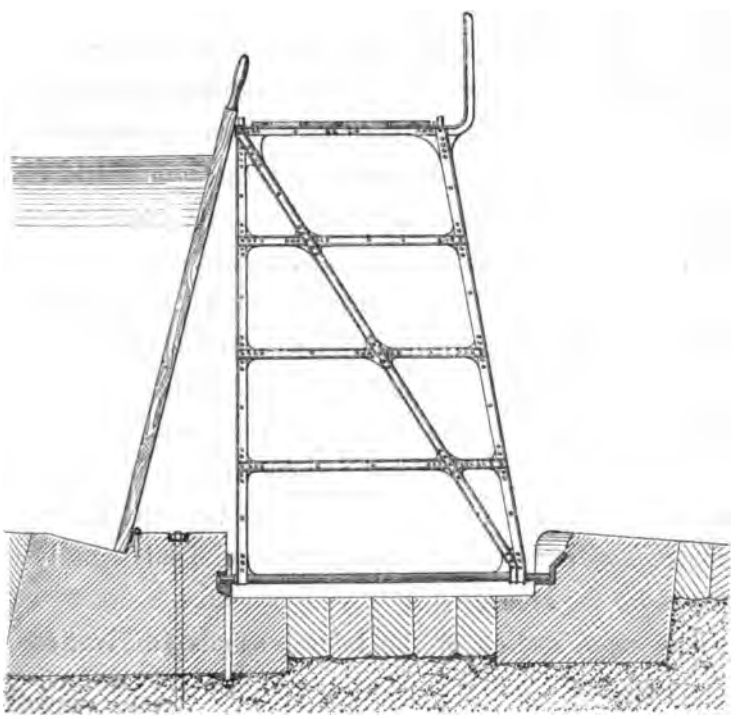
TECHNICAL INFORMATION.

Department of the Ardennes. — The navigation in the department of the Ardennes is carried on in the channel of the river, almost without intermission.

The normal anchoring depth of 2 metres is obtained by means of 22 movable barrages, which are rendered necessary by reason of the slope of the river in this part of its course, and which is not less than $62^{m},86$. The river craft pass these falls by means of short lateral canals furnished at the up-stream end, with gates which protect them from risings of the river, and at the down-stream end with a lock-chamber.

These movable barrages are established after the Poirée system. They consist of a fixed stone sill, which supports a series of iron trestles, strengthened at the upper part by angle-irons. Wooden needles or paddles, forming the water-screen, rest their upper ends against these angle-irons and are held at the lower end by a ledge or projection in the floor.

In the event of a rising of the river, the paddles are re-



Scale of $0^{m},025$ for 1 metre.

moved and deposited on the bank by a person appointed for that purpose. The trestles themselves are laid flat in a

cavity contrived in the floor, so that the water encounters no obstruction capable of increasing its height.

For this purpose, it was necessary to give to the barrages a development of 55 metres, in the upper district of the Ardennes, and this development attains 120 metres, at the boundary of Belgium.

The fixed sill is on a level $1^{m},80$ lower than the normal head of water or water-line, but in case of need it can be raised from $0^{m},30$ to $0^{m},40$.

Telegraphic communication exists between all the barrages, and the keepers are thus previously apprised of the nature of the manœuvres necessary to be operated in time of need. Through this medium, the consignors and consignees of goods will also be placed in easy communication with each other, which is not usually the case.

The locks are $5^{m},70$ in breadth between the chamber walls and 50 metres in length between the mitre-sills, or $45^{m},45$ in the clear between the chord of the overfall wall and the nearest point of the tail-gate-chambers.

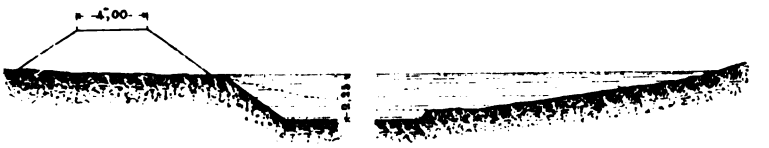
These dimensions are justified by those of the locks already constructed between Givet and Verdun, and which are made for the old-fashioned type of boat usually employed on the Meuse.

The cross section of the lateral canals (dérivations) is

12 metres in breadth at the floor, 2 metres in minimum anchorage, and the talus is 3 metres in the base by 2 me-

tres in height, with a banquette or bench of $0^{m},50$ at the level of the normal head of water.

In the river, the channel is 20 to 25 metres in minimum breadth by $2^{m},20$ or $2^{m},30$ in depth.



For the passage of the boats under the bridges, the height in the clear is fixed at 4 metres.

These works are nearly completed, and the navigation is opened throughout the length of the department.

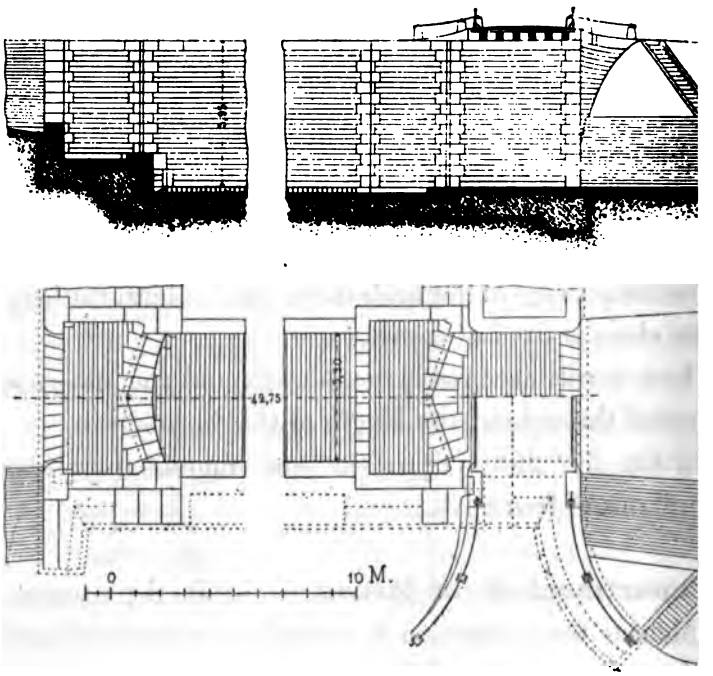
On the 31st July 1879, the cost amounted to about 14 millions of francs.

Department of the Meuse. — In the department of the Meuse, the navigation is carried on almost constantly in a lateral canal. The river is used when necessary, either to supply the lateral canals (dérivations) or for the purpose of crossing certain passages, as the towns of Verdun and Saint-Mihiel, where the formation of a canal would have been attended with exceptional difficulties.

Below Verdun, the cross section of the lateral canals and the dimensions of the locks are the same as in the Ardennes.

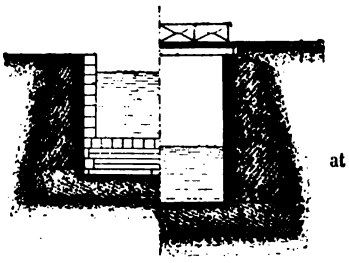
Above Verdun, the breadth of the floor or platform varies from 10 to 12 metres according to local circumstances or obstacles; in conformity with the directions contained in a ministerial order of the 20th July 1877, the locks are

constructed with a breadth of 5m,20 and a length of 38
in the clear, measured as already described. Neverthe



some of the locks, which were completed before the da
the ministerial order above-mentioned, are to be leng

Transversal half-section of the up-stream chamber.

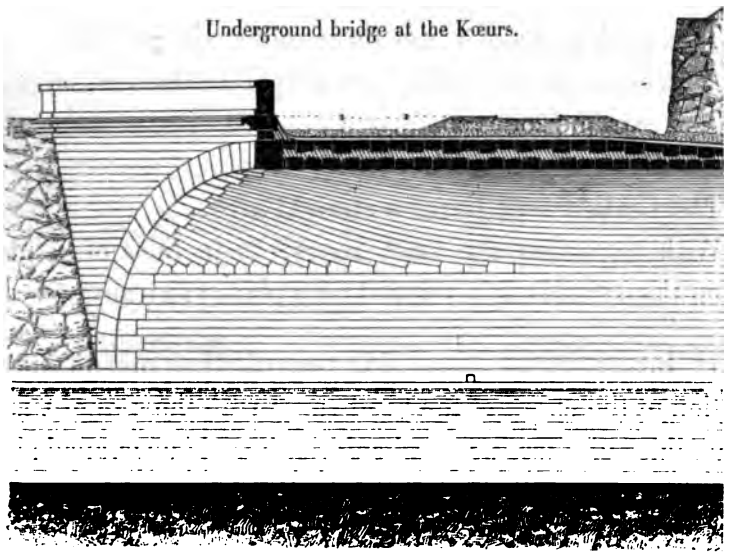


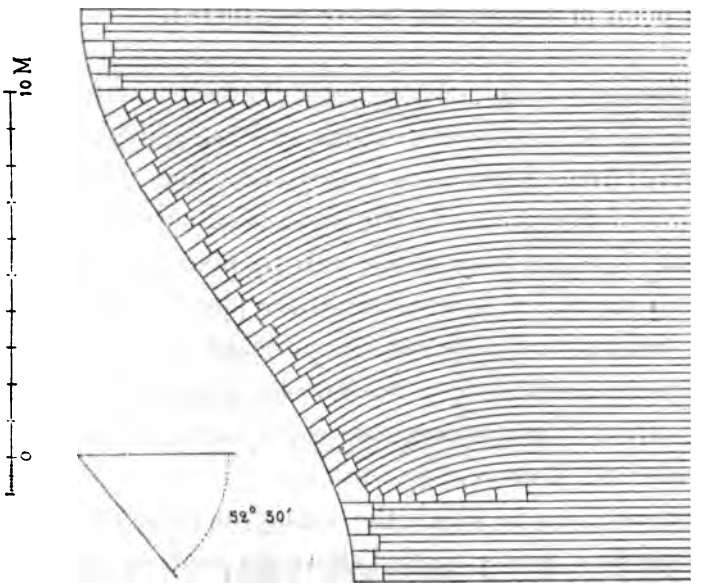
Transversal half-sectior at the axis of the l

ned about 2m,65. The height in the clear under the bri
is fixed at 3m,70.

Among the works worthy of special notice in the Eastern canal, a semicircular tunnel with skew heads, may be

Underground bridge at the Kœurs.





mentioned. It was constructed near the Kœurs (Meuse) and gives an example of a new and greatly simplified convergent method of cutting the stone.

This work is divided into three zones, viz.:

A median zone limited by two perpendicular sections;

Two extreme zones comprised between these sections and planes of the fronts of the arch.

The median zone forms a straight arch.

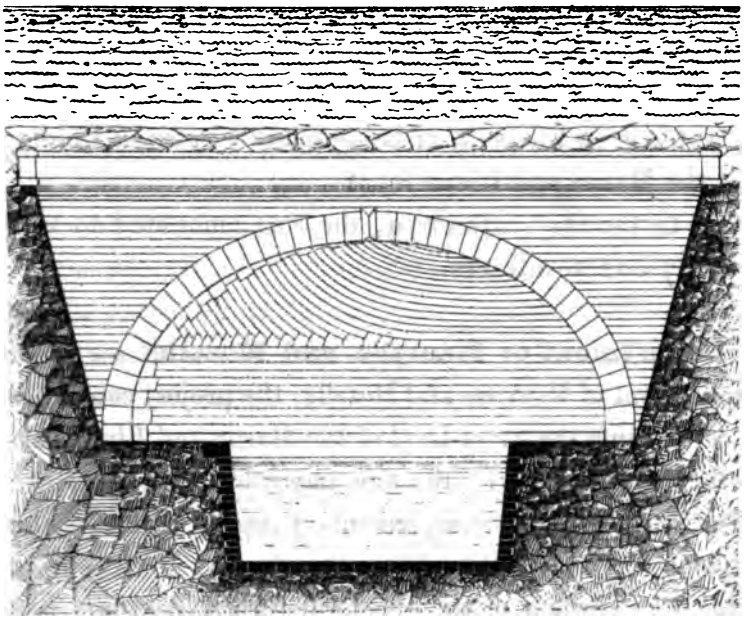
With regard to the head zones, their lines of joints, when the intrados is developed on a plan, are transformed:

1° Into the lines converging towards the point of intersection of the chord of the head curve with the straight line into which the last perpendicular section is developed;

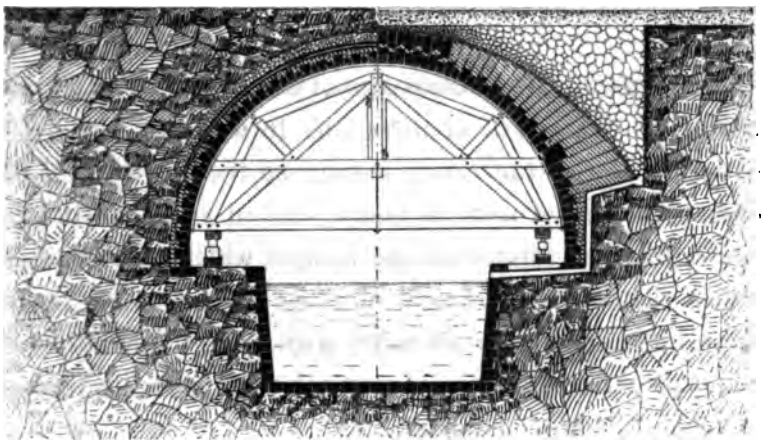
2° Into the orthogonal trajectories of these right lines, i. e. into the concentric circumferences having for centre the point of intersection before mentioned.

This very simple arrangement for a skew arch is derived from the orthogonal convergent system, as the helicoidal is derived from the ordinary orthogonal system, by the substitution of the chords to the sinussoïdal curves of development of the sections of the arch by planes converging towards the line of intersection of the plane of the head with the extreme right section. Its principal advantage consists in giving uniformity to the breadth of the courses and in consequently permitting the employment of ordinary materials and of current dimensions.

In addition to which the arrangement of cutting stone on the skew is only applied above the joints of rupture, and



Elevation of the down-stream head of the tunnel.



Transversal half-section in the tunnel. Transversal half-section in open sky.

Scale of $0^{m},005$ for 1 metre.

from a geometrical point of view it possesses some interesting properties[1].

The works are nearly completed, and the communication by water is on the point of being opened between Belgium and the Marne and Rhine canal.

Up to the 31st July 1879, the cost amounted to more than 17 000 000 francs.

Department of Meurthe and Moselle. — In the department of Meurthe and Moselle, the project comprises:

1° Raising the water-level of the Marne and Rhine canal in the part adopted by the new navigable way.

2° Works for the complementary supply of the reach of Pagny.

3° Canalization of the Moselle between Toul and Pont-Saint-Vincent.

4° Formation of a lateral canal above Pont-Saint-Vincent.

Deepening the anchorage of the Marne and Rhine canal. — The work of increasing to 2 metres the depth of anchorage in the canal, comprised the elevation of the embankments, of work in beton, and in addition, the reconstruction of almost all the bridges which no longer attained the regulation height of $3^{m},70$. The greater part of these operations were attended with special difficulties, it being of paramount importance not to impede the passage of vehicles, trains or boats.

[1] See notice by M. Picard, engineer. (*Annales des Ponts et Chaussées*, December 1879.)

The work was laid out in the following manner :

1° For the stone bridge of the Frouard station, to put the arch on a centre and raise it in one block, by means of screws, after depositing the voussoirs of the springers[1];

2° For the stone skew-bridge at Champigneulles, on the Paris and Strasburg railway, to cut away the arch at the intrados and thus reduce the thickness by $0^{m},44$ along the greatest part of its extent.

The works are entirely completed, and the cost will be about 650 000 francs.

Supply of the Pagny reach. — The great reach or broad sheet of water, by means of which the Marne and Rhine canal is carried without locks from the basin of the Meuse to that of the Moselle, forms a summit-level body of water for the Eastern canal; it is 148 metres above Givet and 39 metres above Toul. The supply was already inadequate to the requirements of navigation and it became necessary to increase it by the addition of three heads of water with hydraulic elevating machines on the Moselle, above Toul. These three machines represent a force of more than 800 horse-power, and each consists of two turbines working, with direct action, three double horizontal pumps with plunger pistons, on the Girard system. One of these systems of machinery was shown in the Exhibition of 1878.

One of the water-works, that of Valcourt, is working in a regular manner; that of Pierre-la-Treiche is also comple-

[1] See the notices by M. Picard, engineer, and M. Bruniquel, principal engineer to the Eastern Railway Company. (*Annales des Ponts et Chaussées*, 1880.)

ted, while the construction of the third, that of Villey-le-Sec, is deferred until necessity shall require it.

Up to the 1st July 1879, the outlay was about 1 2000000f.

Canalization of the Moselle between Toul and Pont-Saint-Vincent. — The works of canalization of the Moselle between Toul and Pont-Saint-Vincent are nearly identical with those of the Meuse in the Ardennes. They were commenced in 1872 and finished in 1874, the cost being defrayed by a special loan of 2 100 000 francs, made to the State by the department of Meurthe and Moselle. They consist of five movable barrages with lateral canals and locks.

Section from Pont-Saint-Vincent to Gripport. — Above Pont-Saint-Vincent, the navigable way presents exclusively the character of a lateral canal; this section includes the most important work of the whole line, viz. a canal-bridge of 120 metres length on the Moselle.

Up to the 1st July 1879, the cost was about 2 200 000 fr.

The works in this section are carried on with great energy.

The Nancy branch. — The Nancy branch will establish a second junction between the Eastern and the Marne and Rhine canal, by crossing the neck, called the Mauvais-Lieu. The length will be 10 kilometres and there will be eighteen locks, five on the slope of the Moselle and thirteen on that of the Meurthe. At present, the works are commenced on the Moselle side only, and on the summit-

level where the cutting affords passage to an aqueduct which carries to Nancy the water drawn from the Moselle by the hydraulic elevating machines.

The supply of this summit-level will be effected by the aid of pumps moved by turbine wheels with horizontal axes, on the Girard system.

The estimated cost of the Nancy branch is about 3 millions of francs, of which sum half is already expended.

Departments of the Voges and the Haute-Saône. — Gripport and Golbey section (near Épinal). — This section, like the preceding one, constitutes a lateral canal, parallel to the Moselle. The works are actively carried on.

The ascent at Golbey. — From Golbey, the navigable way makes a rapid ascent of 45 metres, by the aid of fifteen locks, arranged in echelons or steps, in a valley 3 kilometres in length. It presents the appearance of a series of superposed ponds, separated by embankments and communicating with each other by locks. This work is completed.

Summit-level water. — The body of water at the summit-level is 11 kilometres in length and is open throughout.

It will be supplied by the Bouzey reservoir, which is capable of containing about 7 millions of cubic metres.

A small canal or channel, more than 40 kilometres in length, crosses the Vosges by means of tunnels 1500 metres long, and will pour into the reservoir a minimum

volume of from 8 to 10 millions of cubic metres of water annually; this water will be taken from the risings of the Moselle.

The earth-works of the summit-level consist of two principal cuttings, the cubes of which are respectively 190 000 and 340 000 cubic metres.

This work and that of the foundations of the stone dike of the embankment for the Bouzey reservoir are nearly finished.

Section from Girancourt to Corre. — From the summit-level, the navigation will be carried on by lateral canal, keeping beside the small stream of the Sept-Pêcheurs, and the Coney as far its confluence with the Saône at Corre.

The Saône canalized. — In the valley of the Saône, the navigation will again take the river, by means of movable barrages and lateral canals with locks of the type already described.

Progress of the works. — During the last few months great energy has been displayed in the prosecution of the works in the Vosges and the Haute-Saône. Up to the 31st July 1879, the outlay was about 7 millions of francs.

FINANCIAL DETAILS.

The total of the previous estimates was 65 millions of francs.

It was arranged that this sum should be advanced to the State by a syndicate formed of the five departments of the

Ardennes, the Meuse, the Meurthe and Moselle, the Vosges, and the Haute-Saône, through all of which the new navigable way passes.

The State paid to the syndicate interest at the rate of 4 per cent on the sums advanced in proportion to the payments, and the amount was to be paid off in the twenty years from 1882 to 1901 at the same rate of interest, 4 per cent.

On the other side the syndicate borrowed the 65 millions from the Crédit Foncier, and engaged to pay to that institution:

1° The interest and annuities of repayment that it received from the State;

2° Twenty-eight annuities of 1 050 000 francs payable from 1882 to 1909.

The syndicate was to indemnify itself against the difference between the two rates of interest by the imposition of a toll of $0^f,005$ per ton, per kilometre, and it was duly authorized to levy this toll upon the goods conveyed by the new navigable way.

The departments were also secured against the possible contingency of the amount produced by the toll proving insufficient, by sureties, who bound themselves, if necessary, to supply the deficiency in the toll during the period allotted for paying off the principal; the amount to be paid each year, being 1 150 000 francs for the entire canal, or about 2 300 francs per kilometre. The number of guarantee shares is eighteen hundred and ninety-five, one third of which were subscribed by the towns and communes having a direct interest in the undertaking, one third by representatives of

industry in metals, and the rest by representatives of various commercial interests.

The syndicate is administered by ten titular syndics and five supplementary ones, members of the general councils of the departments interested, and elected by these councils.

By an act recently passed, the collection of dues upon the Eastern canal, as well as upon the whole system of navigable ways in France, has been abolished; in consequence of which, the plans previously described cannot be entirely carried out. Negotiations are commenced with the view of effecting the pure and simple substitution of the State for the syndicate. Nevertheless it seemed proper to recall to mind the particulars of a financial combination which enabled an important enterprise to be undertaken immediately after a disastrous war, and without having recourse to the credit of the State.

The preliminary surveys had been made and studied with a view to the strictest economy; but in 1879, after a careful study of the whole system of French navigable ways, an act was passed 31st July 1879, by which a sum of 31 800 000 francs was added to the previous estimates; this sum was to be expended on the improvements and additions immediately necessary to the navigable way.

By adding the 2 100 000 francs advanced by the department of Meurthe-et-Moselle for the canalization of the Moselle between Toul and Pont-Saint-Vincent, it will be seen that the total sum of the estimates appertaining to the Eastern canal amounts to 98 900 000 francs.

The plans and specifications were prepared and the works

executed, under the direction of M. Frécot, inspector general, by MM. Colle, Poincaré, Volmerange, Holtz and Pugnières, engineers in chief; by MM. Denys, Nicou, de Préaudeau, Bourguin, Holtz, Gottland, Connesson, Picard, Derôme, Cahen, Thoux and Travelet, engineers; by M. Collier, sub-engineer, and by M. Haussser, conductor, doing duty as engineer.

The construction of the hydraulic elevating machines at Toul and Messein, after an open competition, was confided to MM. Callon, professor at the «École centrale», and Feray, constructor at Essonnes.

The preliminary surveys had been made by MM. Frécot, Holtz and Derôme, for the part comprised between Pont-sur-Saône and Sedan; and by MM. Colle and Nicou, for the part between Sedan and Belgium.

APPENDIX.

The establishment of steam elevating machines at Vacon closely connects the construction of the Eastern canal with the amelioration of the supply of the summit-level body of water of Mauvages on the Marne and Rhine canal.

These machines can draw from the sources of the Vacon or the reach of Void (fed by the machines at Toul) 500 litres of water per second, and raise them to a height of 37 metres. Their actual working force in raising the water is 250 horse-power.

They consist of five tubular boilers with feed-water heaters, two steam engines with a single cylinder, with instantaneous introduction and exhaustion; two full speed Gerard's pumps connected directly with the piston-rods.

The water raised is conducted to Mauvages by a stone channel, with cast-iron syphons 1 metre in diameter at the crossing of several valleys.

The preliminary survey was made by M. VOLMERANGE, engineer in chief, and M. COLLIER, sub-engineer. The works were executed by MM. FRÉCOT, inspector general, HOTZ, engineer in chief, and PICARD, engineer. They are completely finished.

The machines were constructed by MM. CAIL and C°.

X

EMBANKMENT WORKS

OF THE MARITIME PORTION OF THE SEINE.

A set of drawings.

Two plans of the embankment on a scale of $\frac{1}{5000}$ ($0^m,01$ to 800 metres).

A comparative longitudinal section

on a scale of $\frac{1}{6667}$ ($0^m,015$ to 1 000 metres) for the lengths

and on a scale of $\frac{1}{200}$ ($0^m,005$ to 1 metre) for the lengths.

Historical statement. — The embankment works of the maritime portion of the Seine have already appeared at the Paris Exhibition of 1867, at the Vienna Exhibition of 1873 and the Paris Exhibition of 1878. Ten years have elapsed since the last extension of the embankments, and the results have definitively realized the expectations entertained in 1867 and 1873.

We shall briefly recapitulate the conditions under which the navigation at the embouchure of the Seine formerly existed, and at the same time give some account of the successive works of improvement.

Rouen is situated 128 kilometres above the entrance of the mouth of the Seine. Of this long distance, half required improvement to render it navigable, and this section comprised a length of 60 kilometres between La Mailleraye and the sea, below Honfleur. The breadth of the river-bed between La Mailleraye and Villequier was 1 000 metres; at La

Vacquerie, 1 500 metres; at Quillebeuf, 3 200 metres; at Marais-Vernier, 4 800 metres; below La Roque, 7 000 metres, and above Honfleur 10 000 metres. This vast extent of water was filled with banks of shifting sand, which were constantly changing place through the action of the violent currents at the ebb and flow of the tide, and it often occurred that in the course of a few days, the position of the channel would be changed from one side of the river to the other. The depth was also variable and insufficient; during the highest tides there was a depth of $4^{m},30$ of water below Quillebeuf, and only $1^{m},76$ at high neap-tides. Many dangers attended the navigation of the river above Quillebeuf: 1° the Flac bank, with $4^{m},55$ at high spring-tides and $2^{m},76$ at neap-tides; 2° the Traverse; 3° the Brindel rock; 4° the Meules bank, where about the same depth was found.

These perils, encountered at intervals of the voyage, were considerably augmented by the tidal wave or bore, and vessels were stranded and wrecked by its powerful action without the possibility of receiving assistance.

Under these circumstances, the navigation was confined to small vessels of from 100 to 200 tons, and the voyage from the sea up to Rouen occupied four days; a great number of wrecks marked the route, freights between the sea and Rouen rose to 10 francs per ton of 1 000 kilogrammes and the rate of insurance was 1/2 per cent.

Such was the state of things previous to the improvements. The first works were undertaken by virtue of an act passed on the 31st May 1846, which enjoined the construction of longitudinal embankments, 300 metres apart, between Villequier and Quillebeuf.

This latter point was reached in 1850, and the success of the undertaking thereby assured. The following embankments were formed in succession; on the right hand, between Quillebeuf and Tancarville (decree of the 15th January 1852); on the left, between Quillebeuf and La Roque (decree of 3rd August 1853); on the right between Tancarville and La Roque (decree of 14th July 1861); and finally the embankments on both banks between La Roque and La Risle, 500 metres apart (decree of 12th August 1863). No further improvements were attempted till 1867, and since that year, they have been limited to connecting the left shore embankment with the coast near Grestain, but the importance of the results obtained justified the stoppage of the works in that direction, thereby allowing them to be continued higher up the river at the point of commencement, thus to be completed by the southern embankment below La Mailleraye, and by the dredging of the Meules bank. At the present time, the embankment of the maritime portion of the Seine terminates on the right of the Risle embouchure, 17 kilometres above the entrance of the bay, and 43 kilometres below La Mailleraye, where the improvements were commenced.

Cost. — The works for the improvement of the Seine were executed in consequence of an act passed on the 31st May 1846, and of seven decrees in succession. At the date of the 31st December 1876, they represented a total outlay of 18 205 830 francs.

Works. — All the embankments were formed in ran-

dom work (*pierres perdues*), by means of blocks of chalk taken from the cliffs bordering both banks of the Seine from Rouen to the sea.

In quarrying these blocks, the natural division of the masses of chalk is utilized by two distinct series of parallel planes, nearly vertical in position; one series is usually parallel to the course of the Seine and to the front of the quarry, while the other forms with it an obtuse angle. An excavation is made in a soft layer at the foot of the mass, leaving on both sides the planes of the natural division, and is deepened for several metres until the parallel plane of division is attained in front. Pillars are left to support the roof of the excavation, and their removal brings down the whole mass from the upper part of the cliff. In this manner, 500 cubic metres of stone are detached at once, and afterwards broken into regular blocks of from $0^{m},40$ to $0^{m},60$ in thickness, by means of blasting and the use of gads.

Pieces of the smallest dimensions, and even the loose rubbish, are used at the same time with the larger blocks, in order to reduce the empty space in the enrockments; but each kind is supplied separately.

Vessels of from 30 to 70 tons burden are employed to carry the materials. These are stowed on the deck, and the cube is given according to the measurement of the vessel, which has been previously gauged for that purpose.

The embankments were constructed in random work, and are divided, according to their height, into two distinct types: some were raised above the level of the highest tides, while others were capable of being submerged, in order not to interfere with the general tidal system.

The system of high embankments was employed on the right bank as far as Tancarville, and on the left, as far as La Roque; beyond these points and to their extremities, the embankments are low. At La Roque, the level of the top on the left bank is $1^{m},34$ above low water at average neap-tides, and $2^{m},10$ above low water at average spring-tides. The right embankment was raised $0^{m},45$ higher than the left.

Reasons of economy have since led to the formation of a low embankment below La Mailleraye, on the left bank, and at other points.

Since their construction, the embankments have suffered great damages. One of the principal causes of the deterioration of the high embankments, has been the influence of the works upon the height of the ebb-tides, and which has considerably lowered their level; at Quillebeuf for instance, the average level of low spring-tides was, in 1862, $1^{m},60$ above the present mark; during the high tides the level of the ebb is $0^{m},33$ below this average, while formerly it was at neap that the tide attained its maximum depression. At Caudebec, the difference between the average low-water mark of the spring-tides in 1862 and the present time, is $0^{m},69$.

The tidal wave acts strongly upon that part of the embankments situated immediately above low-water of spring-tide, and the gradual lowering of this level has caused a change in the direction of the tidal wave, therefore the destruction caused by it has, in consequence, been greatly augmented. The tidal flow having now become to a certain extent, more constant and regular, the definitive consolida-

tion of the high embankments has been undertaken, by means of stone-packed risberms, protected by a line of piles and sheet-piling.

The low embankments are not subject to the action of the tidal wave, which is not perceived in their quarter, but they are 4 metres under water, at average spring-tides, and the force of the currents crossing them, is productive of much injury, which is in course of being obviated by means of stone-packing.

Tidal wave or bore. — It is here necessary to advert to the tidal wave, that powerful volume of water which, in the Seine, precedes the flood-tide, and rushing up the river, dashes against the banks with great violence.

It was hoped that, by giving greater regularity to the bed of the river, the effects of the wave would have been considerably modified, and at certain dates this desirable result was, in fact, produced; but the periods of calm were not of long duration, and the tidal wave still acts with intense force. It is scarcely perceptible between the sea and Tancarville, but at that point it begins to increase; the maximum height is attained at Quillebeuf and continues as far as above Caudebec, while beyond the Meules bank it loses nearly all its force.

At the present time, the tidal wave is no longer an object of dread as regards the shipping; vessels are no longer stranded, and are enabled to support the shock of the wave without inconvenience.

Result of the works. — The effect of the works has

been to modify the bed of the river and the course of the channels at the embouchure, the navigation has consequently undergone an entire change; and at the same time large meadows have been created.

The bed of the stream where it is embanked, has increased in depth beyond the most sanguine expectations, and a comparison of the longitudinal sections of the river in 1829 and in 1877 will sufficiently demonstrate the fact. The bed has deepened 7 metres at the Traverse or bar of Villequier, 4 metres at the Traverse of Aizier, 9 metres below Quillebeuf, and 5 metres at La Roque; in addition to which, it may be stated that the Meules shoal has been lowered 3 metres by means of dredging.

The effect of the works is not less remarkable below the embankments, as the extent of the estuary (17 kilometres) allows the channel to change freely; it is in consequence far from being completely fixed, but no comparison can be instituted between these slight oscillations of position, and the abrupt displacements formerly so frequent.

The Meules bank remains the most elevated shoal in the river.

In 1879, the water attained a height of $8^{m},12$ at high spring-tide, and has never been below $4^{m},76$ at high neap-tide. During two days only, the depth of water at flood tide was below 5 metres.

Navigation has progressed concurrently with the improvement of the river. In 1852, 3 677 vessels with 351 014 tons of cargo of various descriptions entered the port of Rouen. The average lading of these vessels was 95 tons. The ton-

nage of the cargoes leaving Rouen was 324 775 tons, which gives a total of 675 789 tons.

In 1861, 2 692 vessels entered the port, carrying 272 477 tons or an average lading of 100 tons. The cargoes leaving the port, were estimated at 269 604 tons, thus giving a total of 542 081 tons.

In 1878, the entries were 755 sailing vessels carrying 166 102 tons (average lading 220 tons), and 1 041 steamers carrying 508 926 tons (average lading 489 tons). The aggregate tonnage of the port attained 876 798 tons (arrivals and departures included).

If we add to this amount 117 235 tons for transhipment, and 121 359 for the arrivals and departures of the fluvial basin, we shall obtain a total of 1 115 392 tons for the maritime navigation of the Seine below Rouen.

The tonnage of steamships arriving, has increased from 111 367 tons (in 1869) to 508 926 (in 1878); the relation of the latter number to the former is 4,57.

In 1878, there arrived in the port 165 vessels drawing more than 5 metres of water; 229 drawing from $4^{m},51$ to 5 metres; 376 drawing from $4^{m},01$ to $4^{m},50$, and 259 with a draught of from $3^{m},51$ to 4 metres.

In 1867, a Hamburg vessel, drawing $4^{m},30$ arrived in the port of Rouen.

In 1873, the port was deepened sufficienthy to admit an English vessel drawing $5^{m},19$.

And finally we may mention the arrival of the English ship *Tyro*, which entered the port on the 12th July 1877, drawing $6^{m},40$ of water.

The freight between Rouen and Havre was formerly

10 francs; since 1867 it has fallen and is quoted at 5 francs.

The passage from the sea to Rouen is made in eight or ten hours, and from Rouen to the sea in one or two tides at the most.

The maritime position of the Seine terminates at Rouen, and the development of this port shows the value of the amelioration effected by the embankments.

We must not however omit to mention the more modest progress of three ports of minor importance, situated between Rouen and the sea; they are : Duclair, La Mailleraye and Caudebec. In 1878, the maritime commerce of Duclair was 17 100 tons; of La Mailleraye 10 478 tons; and of Caudebec 15 953 tons.

Alluvial Lands. — Behind the embankments and in the parts formerly occupied by the shifting sands, alluvial meadows have been formed, of which the superficial extent is 8 400 hectares.

They are divided into three classes : lands made over to the river-side proprietors; lands belonging to the State; and lands in course of formation.

1. The State made over 2 613 hectares, to the river-side proprietors and received an indemnity of 1 389 200 francs.

2. An extent of 3 710 hectares yields a profit to the Treasury every year, by the rent of the pasturage. In 1878, it amounted to 295 575 francs.

3. A superficial extent of 2 077 hectares is in course of formation.

At the present time, it is a fact well established that the alluvial meadows are of excellent quality and that they are actually worth 4 000 francs per hectare; it follows from this, that the 2 613 hectares made over to the river-side proprietors are worth 10 452 000 francs, and the value of the 3 710 hectares still belonging to the State, is 14 840 000 francs. When the alluvial lands in course of formation are definitively constituted, the total value of the lands formed by embankment will be 33 600 000 francs. Lastly, it is worthy of observation that these calculations only include the lands above the actual limit of the embankments, and that the influence of these works extends a long distance beyond them into the bay; the stability of the channel has led to the formation of vast meadows, the possession of which is claimed by the State as sea alluvions.

These statements show the results obtained.

During the period of construction, viz. from 1848 to 1867, the works were directed by MM. Doyat, Beaulieu, Emmery and Du Boulet engineers in chief; MM. Partiot and Godot engineers. The superintendence principally devolved upor M. Sadlucki, conducteur.

Since 1867, the service of the maritime portion of the Seine has been directed successively by MM. J. Lemaître, Bellot and Chanson, engineers in chief, and by MM. Alard, Juncker and Cartault, engineers.

FOURTH SECTION.

MARITIME WORKS.

XI

PORT OF MARSEILLE.

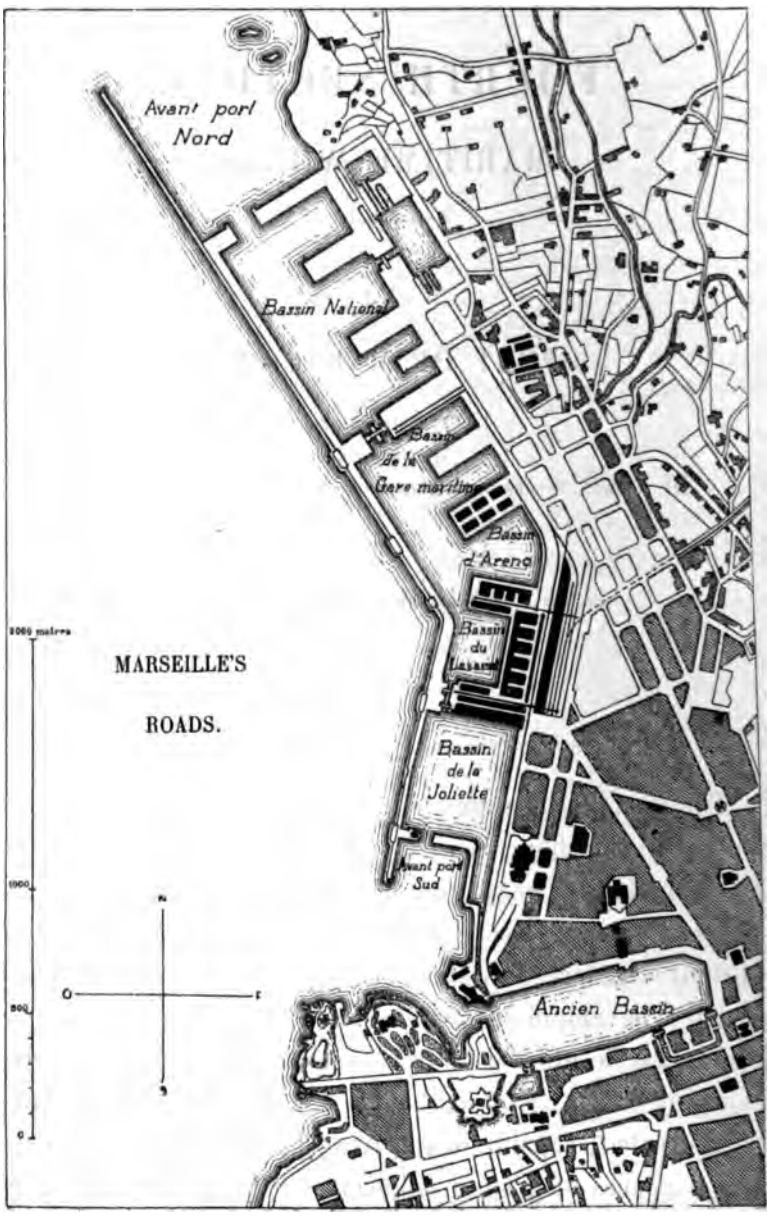
I. EXTENSION OF BASINS.
II. DRY-DOCKS.
III. BRIDGE, EITHER DRAW-BRIDGE OR SWING-BRIDGE AT DISCRETION.

Picture. Bird's eye view of the port and town.

I

EXTENSION OF BASINS. — GENERAL INDICATIONS.

The port of Marseilles, which in 1844 only possessed the old natural harbour, with a superficies of 29 hectares and 2700 metres of quay, comprises, at the present time, a series of exterior basins all reclaimed from the sea, which present a surface of, water perfectly sheltered 136 hectares of and a development of quays of 12600 metres, 8500 of which can be utilized for the purposes of loading and discharging cargo. Around the basins, vast warehouses have been erected, capable of receiving 130000 tons of goods. Large spaces of ground adjacent to the basins will augment the importance of the warehouses, and lastly, five dry


Avant port Nord
Bassin National
Bassin de la Gare maritime
Bassin d'Arenc
Bassin du Lazaret
Bassin de la Joliette
Avant port Sud
Ancien Bassin
MARSEILLE'S
ROADS.
2000 mètres
1000
500
0
N
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docks, one of which is 141m,50 in length, afford all necessary facilities for the examination and repair of vessels of every class. Vessels of the largest size can enter the port, and the *Great Eastern*, 200 metres in length, could load and discharge without inconvenience. The trade of the port amounts to 20 000 ships of five millions of tons burden, arrivals and departures taken together.

The works in course of execution at the present time, in the Basin of the Maritime Station and the National Basin, will, at no distant date, greatly augment the resources of the port. When they are finished, Marseilles will possess an ensemble of basins having a superficial extent of 140 hectares, surrounded by quays 17 kilometres in length, of which 13 kilometres can be utilized for loading and discharging, and presenting collectively a superficies of 64 hectares. Of this extent, 21 hectares will be available for public ways, 23 hectares for warehousing purposes, and 20 hectares for the development and working of the Docks and Bonded Warehouses[1].

The depth of water varies in the different basins. In the old basin, it is from 6 to 7 metres below low tides, while the new basins have, a few places excepted, a minimum depth of 7 metres, and for an extent of more than 50 hectares, the depth exceeds 9 metres. Along the exterior dike of which the total length at the present day is 3 070 metres, the depth of water ranges successively from 11 to 15 and 20 metres.

There are three passages, with a depth of water as fol-

[1] The Docks and Bonded Warehouses of Marseilles are leased by a company for 99 years dating from the 1st January 1864.

lows : that of the old port, $7^{m},50$ below the lowest tides; the southern passage of the new basins, 9 metres, and the northern passage, 15 metres.

In the elaboration of the plans of the exterior basins, the prominent feature consists in the formation, along the shore, of a series of basins separated from each other by interior moles or causeways, built into the bank, protected on the side next the sea by a dike parallel to the coast, and leaving, between it and the ends of the moles, a channel sufficiently large to permit of easy communication between all these basins. This plan allows the capacity of the port to be always proportioned to the increasing requirements of commerce, by adding new moles in succession to those already existing, and protecting them by a corresponding extension of the exterior dike.

The sums expended upon the port of Marseilles, not including the warehouses, amount since 1844, the period at which the new basins were commenced, to 50 millions, and this total will be augmented to 70 millions, after the completion of the works in course of construction.

System of construction. — Exterior dike. — The exterior dike of the port of Marseilles is formed of natural and artificial blocks.

Several important works of a similar nature were in existence at the time when this dike was projected. There were the breakwaters of Cherbourg in France, and Plymouth in England, and others were being actively carried on, viz. the mole of Algiers, and the breakwater of the Delaware, in the United States; and finally, the Holyhead

breakwater, a work of great importance, was under consideration nearly at the same time as that of Marseilles.

The principal idea by which the projectors of the great breakwaters of Cherbourg, Plymouth, Holyhead and Delaware appear to have been actuated, is that of employing simultaneously vast quantities of stone from the adjacent quarries, and leaving to the sea the care of forming the slope or talus intended to be permanent.

In addition to this paramount idea, another suggested itself, viz. that of reserving the large material to cover the exterior talus of the mass forming the main body of the work. Thus at Cherbourg, a course of large blocks, $1^{m},25$ in average thickness, was deposited on the talus and sunk to a depth of nearly 5 metres below the lowest water mark, beyond which limit in that locality the powerful action of the waves does not extend.

Nevertheless, in the parts of the breakwater most exposed to the action of the waves, and in those that it imports particularly to protect from injury, these blocks do not appear to afford sufficient security, and in their turn are being covered by artificial blocks of 20 cubic metres.

Thus at Plymouth, the exterior talus is pitched with blocks 80 centimetres in thickness by $1^{m},20$ in length and 1 metre in breadth, held together by Parker cement.

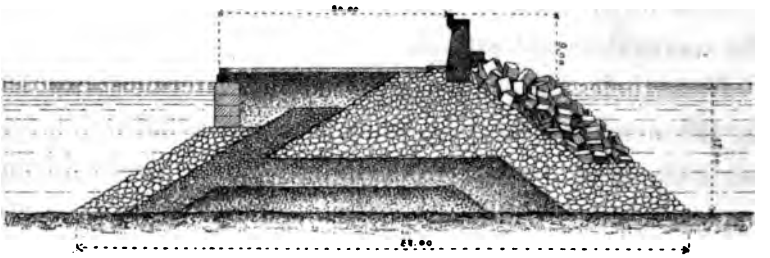
In the Delaware breakwater, blocks of 4 000 to 5 000 kilogrammes are employed for the defence of the talus, and are set regularly as bonders.

A similar method prevails at Holyhead.

The mole at Algiers is planned upon a totally different system. The projector believed it imperative to use only

blocks of such dimensions as would preclude the possibility of displacement by the waves. And this appeared to him an idea well-founded, seeing that the action of the wave is in proportion to the surface struck, while the resistance of the block increases as its cube. The work was therefore accomplished by means of artificial blocks, first of 10 and afterwards of 15 cubic metres.

In the breakwaters of Cherbourg, Plymouth, Holyhead, and the Delaware, the exterior talus varied according to the position of the work, between 5 and 10 to 1, within the zone of action of the waves, an action which had an appreciable effect at nearly 5 metres below the lowest tide, but experience has demonstrated that the talus of the mole at Algiers preserves an inclination of about 1 $\frac{1}{4}$ to 1.

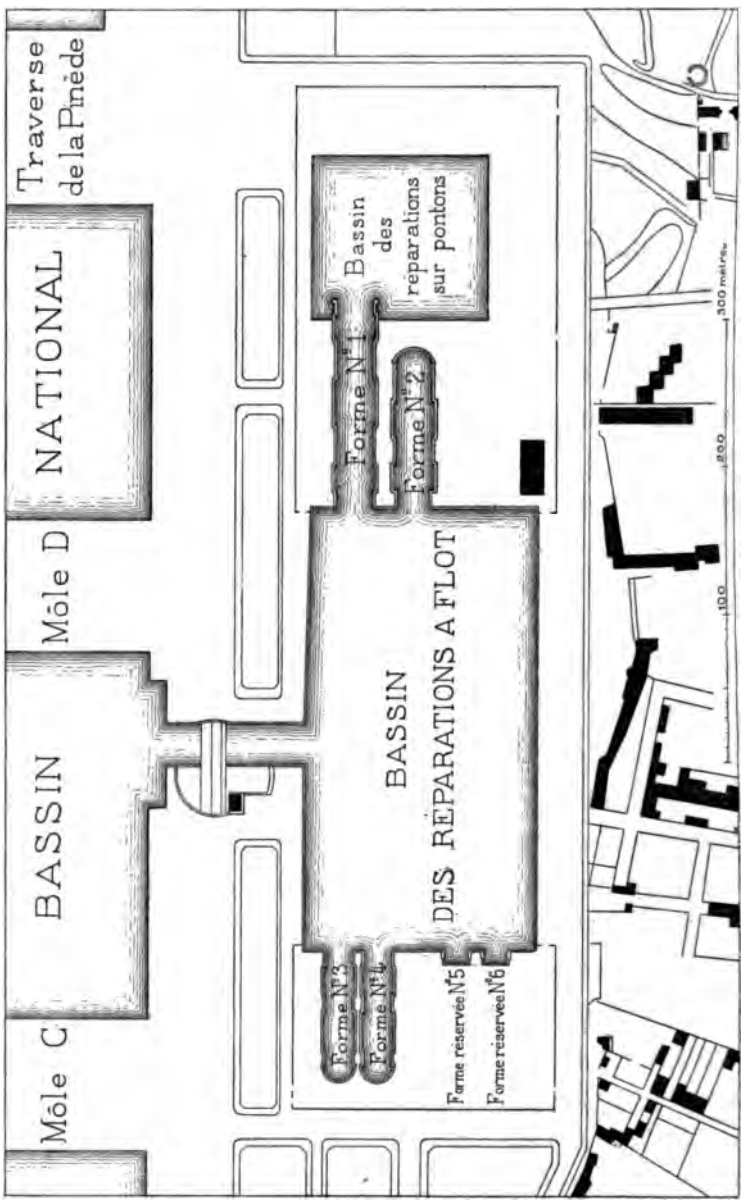


The dike at Marseilles has been constructed upon a system embodying the combined experience of Cherbourg and Algiers. On the one hand, the idea of directly opposing the powerful action of the waves by enormous blocks, artificially constructed, has been taken from the mole at Algiers, while on the other, the breakwater at Cherbourg suggested the employment of natural blocks of all dimensions, to constitute the main body of the work. The former serve as a facing to the latter, and in the present instance

both have been used simultaneously, in such a manner as not to leave the natural blocks exposed to the great force of the waves. As this force sensibly diminishes at a depth of 5 metres below ebb-tides, the use of artificial blocks has been limited to 6 metres below that level.

With the twofold view of solidity and economy, positions have been assigned to the natural blocks according to their respective dimensions. This course has been adopted in preference to the plan followed in the construction of the works already mentioned, in which the stone was used indiscriminately as it came from the quarry. From considerations of economy, the small materials have not been mixed with the large, in order to preserve the greatest possible void. With a view to solidity, the large blocks have been so disposed as to entirely surround the small ones.

Experience has fully confirmed the rationale of these ideas. That part of the dike which protects the Basin of La Joliette, was commenced 27 years ago; and that which shelters the basin of the Marine Terminus dates from 16 years, while it is one year since that of the National Basin was completed. Now all these parts of the dike are, at the present time, is an excellent state of preservation, and if at the inauguration of this system 36 years ago, some reserve was necessary in expressing an opinion upon its efficiency, and it was admitted that the never failing test of time could alone pronounce a reliable verdict upon this point, these considerations no longer exist, since time has satisfactorily demonstrated the excellence of this system, which cannot fail to be generally adopted by reason of its remarkable economy.


Traverse de la Pinède
NATIONAL
Môle D
BASSIN
Môle C
Bassin des réparations sur pontons
Forme N°1
Forme N°2
BASSIN DES RÉPARATIONS A FLOT
Forme N°3
Forme N°4
Forme réservée N°5
Forme réservée N°6
100
200
300 mètres

Interior moles. — The interior moles are formed by ıeans of quay walls which constitute the outer part, and re filled in with ordinary rubbish, brought to the enclo- ure thus prepared.

The quay walls rest on a sub-marine foundation of nat- ral blocks, on which is laid an upper course of artificial nes. These are laid dry in perpenders with breaking joints, o a depth of 6 metres below the level of the lowest tides. n the works now constructing this depth has been increased o 7 metres.

The system of artificial blocks superposed without nortar is perfectly adapted to all works constructed, upon ground of a precarious or moving nature, such as sub-ma- ine walls if recently built.

II

DRY-DOCKS.

The dry-docks occupy a rectangular space of ground, 745 metres in length by 280 metres in width, to the east of the national basin and parallel to it.

They comprise at the present time :

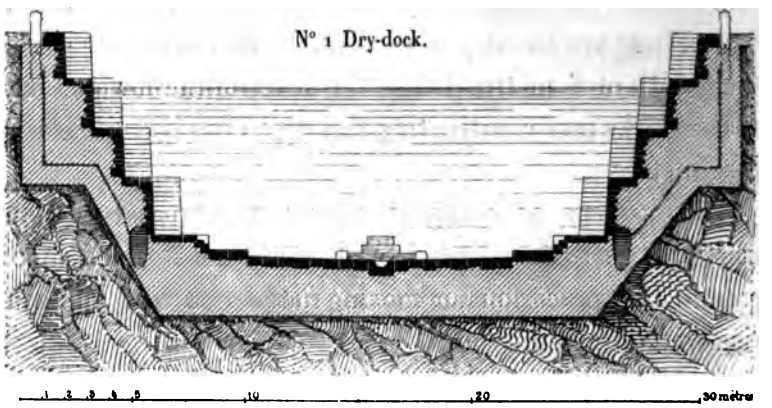
1. A basin for repairing vessels while afloat, forming also an outer basin, 360 metres in length by 160 metres in width, and having a depth of water of 8 metres.

2. Four dry docks in masonry completely terminated, and two new ones commenced.

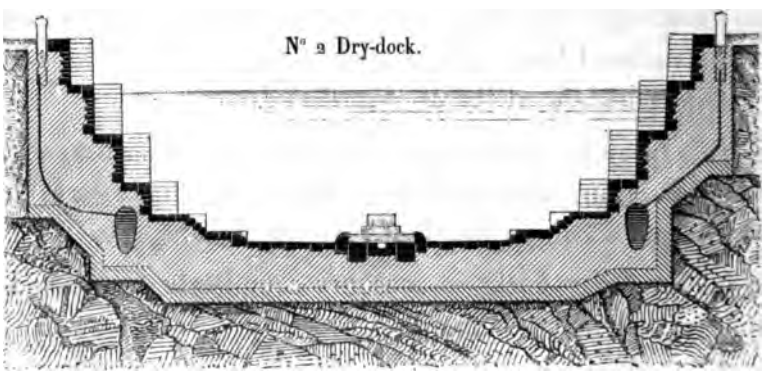
3. A canal 28 metres in width by 92 in length and 8 metres in depth, connecting the repairing basin with the National Basin.

4. The ground necessary for the establishment of work-shops, and for increasing the number of dry-docks to eleven.

Up to the present time those finished are :

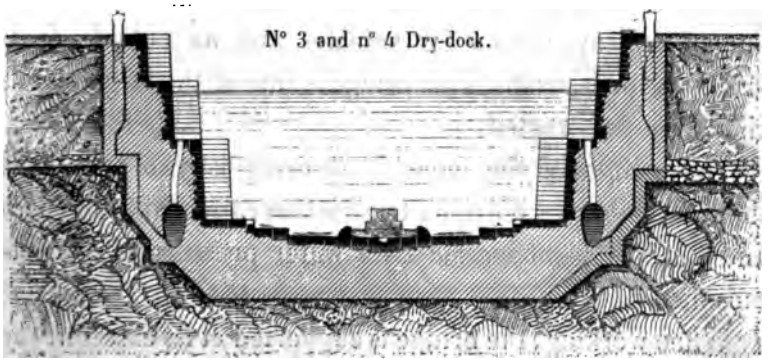


N° 1, the largest dock is 141m,50 in length with a depth of water of 7 metres below ebb-tides.



N° 2 is 110 metres in length with 6 metres of water.

N^os 3 and 4 are 90¦ metres in length with 6 metres of water.



N° 3 and n° 4 Dry-dock.

The longitudinal gradient of these docks is $0^{m},01$ per metre.

All the works of the repairing docks have been executed dry, by the aid of a coffer-dam in beton 1218 metres in length. This dam was established on a bottom of rock or hard clay, varying in depth from 0 to 11 metres.

The caissons which close these docks consist of an iron water-tight hull, which can be floated or grounded without the assistance of pumps, by the simple process of regulating the quantity of water which serves for ballast.

The machinery for pumping out the docks consists of four separate steam engines working four centrifugal pumps which, when in action together, are capable of raising ten thousand cubic metres of water per hour to a height of $4^{m},50$.

This power, much in excess of actual requirements, has been established in view of an augmentation of the number of docks, which, as before stated, can be increased to eleven.

The entrance of these dry-docks is 28 metres in width, and is crossed by an iron swing-bridge of a single bay, 62 metres in length by $15^{m},94$ in breadth, having a single line of railway, a road for vehicles and an outside foot-bridge for pedestrians. This bridge is one of the largest of its kind ever constructed.

The weight of the movable flooring is 700 tons, and the rotation is effected upon two friction rollers at the breech and a central pivot, raised by a water pressure of 270 atmospheres.

When working, the bridge is supported at its extremity by three wrought iron rollers which permit expansion. At the end of the breech it bears on three conical wedges, worked simultaneously by a connecting bar; lastly, in the central part, on a cross-beam resting on squared blocks of stone.

The opening of the bridge gives rise to three operations: 1. Unwedging the end of the breech; 2. raising the bridge by means of the hydraulic press till the supports at the extremity of the flap (*volée*) are completely disengaged; 3. rotation. These three operations require 2 minutes 58 seconds. The closing of the bridge is effected by three operations, reversing those preceding, and is accomplished in 3 minutes 2 seconds.

Whatever may be the force of the wind, one man suffices to perform these manœuvres though the wind is sufficiently strong sometimes at Marseilles, to delay the departure of vessels.

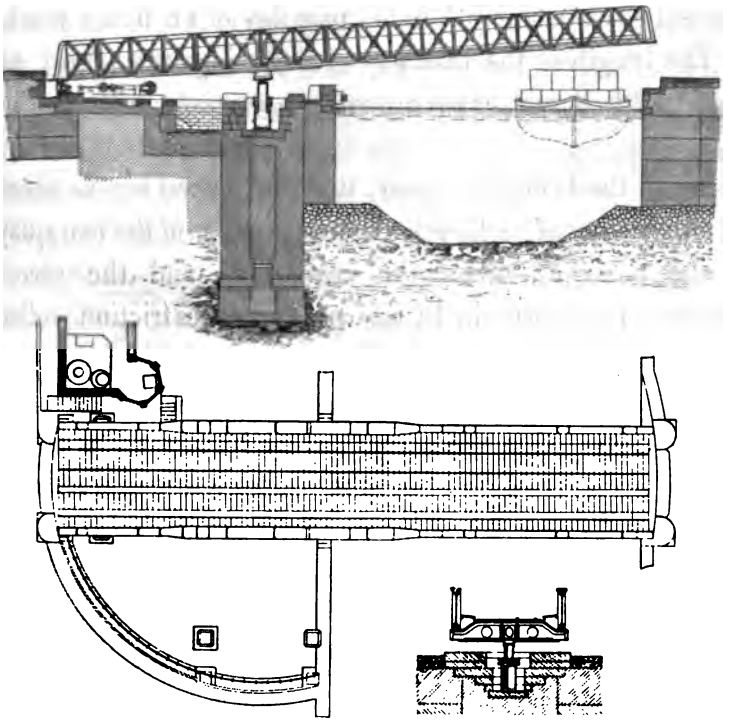
The bridge rests on a circular block of stone-work $9^{m},50$ in diameter, and is founded on hard clay, at a depth of $8^{m},30$ below ebb-tides.

The docks for the repair and inspection of vessels have cost 8 000 000 francs.

III

BRIDGE, EITHER DRAW-BRIDGE OR SWING-BRIDGE AT DISCRETION[1].

This bridge is established on the passage of La Joliette, which is 21^{m},30 in breadth. It has a double action : one of rotation, as in most movable bridges; the other of raising



the flap (*volée*). This arrangement was judged expedient from the following considerations.

[1] See detailed description of the bridge in the collection of drawings of the «École des Ponts et Chaussées», vol. II, p. 410.

The daily maritime circulation through La Joliette passage consist of about ten masted vessels and forty barges or lighters. The complete rotation of the bridge is required for the vessels, but the passage of the barges is effected by partially raising it, which is accomplished in less time than the rotation. By this double arrangement, much time is saved in the successive interruptions of the traffic on the bridge. The total loss of time caused by the interruptions is under present circumstances 4 hours in a day of 10 hours work.

The length of the iron bay of the bridge is $41^{m},09$ and its breadth 8 metres, comprising a carriage way and two foot ways.

When the bridge is closed, it rests on fixed blocks placed in four points of its length, viz. on the tops of the two quays of the passage, under the cross-beam and the second upright of the breech. In this position the friction rollers are separated from the circular rail on which they turn, by a space of 3 centimetres.

The manœuvres are accomplished by means of an hydraulic pressure of 52 atmospheres, from the accumulators of the Dock Company.

The water is introduced into a vertical hydraulic press, the piston of which, placed a little out of the centre of gravity of the flooring in relation to the breech, assists in raising the bridge and also serves as a pivot for its rotation.

When the piston rises, the bridge being raised, turns round the horizontal line constituted by the support of the breech friction rollers, until these latter have descended sufficiently to bear upon the rail. From this moment it is

the new support that forms the horizontal hinge of the flooring and this latter detaches itself from the nearest blocks, as it had previously done from the others.

For the rotation, the rising of the pivot is arrested at 20 centimetres. For raising the bridge completely, it can be elevated to 90 centimetres. The inclination of the flooring is then 68 millimetres per metre, and the clear height between the average tidal level and the bottom of the flap (*volée*) is $4^{m},60$ at its extremity, while the height under the bridge when in use is only $1^{m},80$.

The diameter of the piston is $0^{m},85$ and its length 2 metres, so that when it rises to the full extent, there is still a length of $1^{m},10$ in the press.

All the manœuvres are executed with the greatest facility, by one man at the press, and from a place close to his lodging, he can manage the working of the bridge.

The weight of this bridge is 300 tons, and it rests on a stone pier 6 metres in diameter, founded on the rock, by means of a caisson with compressed air, at a depth of 14 metres below ebb-tides.

The total outlay was.	316 000 fr.
For the bay, not including the masonry of the approaches.	250 000 fr.
For the foundation pier.	66 000
Total.	316 000 fr.

The great works of the port of Marseilles date principally from 1844. From that period till 1857 they were successively directed by MM. Toussaint, Bergis, Montet, de Montricher and Pascal engineers in chief. Since 1874 they have

been directed by M. Bernard engineer in chief, MM. André and Guérard and M. Sébillotte principal conducteur, acting as engineer.

Among the conducteurs that have assisted the engineers, mention should be made of MM. Bullier, Levens, Coignard, Sébillotte, Pissère, Bénézeth and Bompard.

The contractore were MM. Dussaud brothers, Barthelon, Rabattu, Vaccaro, Michel (Désiré), Dupuy and Magnac, Lobin and Ferchat.

The floating gates, the pumping machinery and the swing-bridge were planned by M. Barret, engineer to the Dock Company, and executed by the New Mediterranean Iron-Works Company, under the direction of this engineer.

XII

THE BORDEAUX BASIN.

(DEPARTMENT OF THE GIRONDE.)

Dry dock and Lock Gates.
Painting. Bird's eye view of the port and town.

In 1867, it was decided to form a wet dock or basin at Bordeaux, with the view of enlarging the port, of which the natural resources were recognized to be entirely inadequate to its maritime and commercial development.

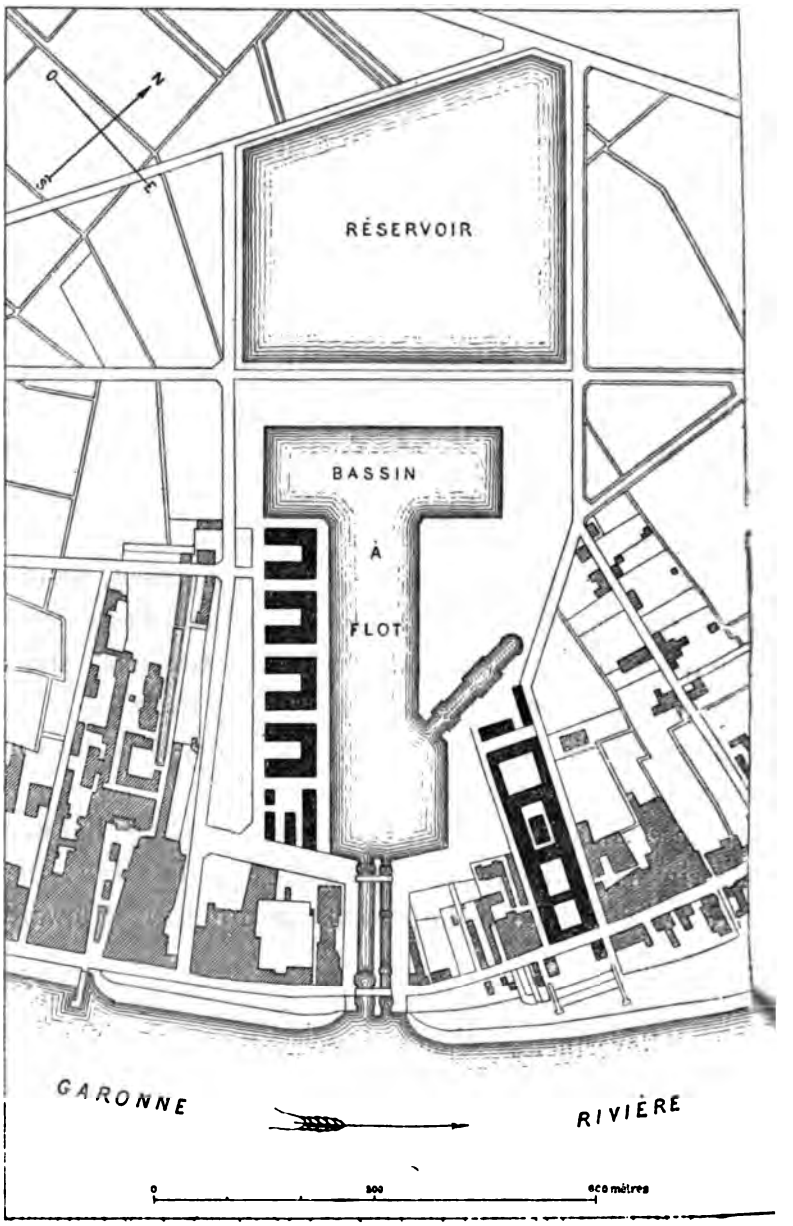
The first improvements projected, comprised, besides the basin properly so called, the channel and locks necessary to put it in communication with the Garonne, and a reservoir for the water necessary to supply them.

These works were supplemented by a dry-dock, the construction of which was decided on in 1873.

These undertakings were commenced in 1869, but were interrupted by the war of 1870 and 1871. In 1872, they were resumed, and at the present time are drawing towards completion.

The basin was opened for shipping on the 20th October 1879. Nevertheless some accessory arrangements are not yet entirely carried out, and some earthwork operations remain to be executed.

Brief description of the works. — The Bordeaux


O
N
RÉSERVOIR
BASSIN
À
FLOT
GARONNE
RIVIÈRE
0
200
400 mètres

basin is situated on the left bank of the Garonne, in the Bacalan quarter, between the marine provision store and the porcelain manufactory, and at a distance of 2 500 metres from the Bourse. It is nearly at right angles to the river, while it extends 750 metres along the Bacalan quay, and occupies with its dependencies an extent of 52 hectares.

Heights. — The heights which follow, refer to the low-water mark of the Garonne in the port of Bordeaux; the plane of comparison corresponds to the zero of the scale or gauge on the second pier of the right bank, of the stone bridge. The figures are marked + or —, according as the measurements are above or below low-water mark.

Highest flood-tide known		+6 45
Average spring flood-tide		+5 13
Average neap flood-tide		+3 92
Smallest flood-tide known		+3 19
Average tide		+2 79
Average spring ebb-tide		+0 97
Average neap ebb-tide		+0 89
Lowest ebb-tide known		—0 11
Mitre-sills of locks		—3 00
Sill of dry-dock		
Platform of basin.	at entrance of locks	—3 50
	up-stream	—3 00
Foundation bottom of	lock platforms	—6 50
	dry-dock	—6 70
Bed of sand on which rest the foundations	locks	—6 30
	quays walls	—5 94
	dry-dock	—6 50
Crown of chamber-walls of locks, of dry-dock and of quay walls		+7 00
Middle of flooring of swing-bridge		+7 65

Basin proper. — The normal breadth of the basin is 120 metres and the length 592 metres, reckoned on the axis. At the western end it takes a turn each way in the form of a T, for a distance of 90 metres to the right and 115 metres to the left, with a breadth of 120 metres.

At the approaches of the locks on the left hand 40 metres farther back, is a wet dock or inner basin 140 metres long, intended for the large mail-steamers and to facilitate the movements of vessels.

The superficial extent of water in the basin is 10 hectares, and it is surrounded by vertical quay walls 1 800 metres in length.

Quay walls. — The crown of the quay walls is 7 metres at the slope; they are from 10 metres to $10^{m},50$ in height according to the depth of the bottom, with an average thickness equal to 40/100 of the height. On the basin side the section presents the form of a concave parabolic curve, of which the lower elements are sufficiently sloped to enable them to correspond to the hull of a vessel; the upper elements unite tangentially at the summit of the wall and present a batter of 1/20.

Counterforts are built at intervals of 50 metres, in order to divide the action of the thrust.

The foundation was commenced on piling, and this method was applied to the wall of the right bank for a distance of a 600 metres above the locks; the other parts were established on a succession of semicircular arches of 8 metres span, and 12 metres from axis to axis; these arches rest on blocks 6 metres long by 5 metres broad, sunk in the bottom

The empty space in the arches is filled in with masses of dry stone-work which support the earth backing of the wall.

Quays and ground. — A loading and discharging quay of 18 metres in breadth, on the south side, and 12 metres on the west and north, will occupy the ground surrounding the basin. Behind are spaces intended for warehousing goods, and connected by a circle of roads 20 metres in breadth, which communicate with the port, the town, or the railways.

The ground intended for goods has a superficial extent of 12 hectares 50 ares. This includes a site of 5 hectares 50 ares appropriated, by the Act of the 20th May 1868, to the Chamber of Commerce of Bordeaux, for the purpose of forming bonded warehouses, which were commenced in July 1877.

Supply reservoir. — Beyond the West quay of the basin is a reservoir of 16 1/2 hectares of superficial extent; it communicates with the basin by means of an aqueduct fitted with sluice-gates and stop-planks. The water is not yet supplied in a regular manner.

When the works are finished, the level of the water in the basin will be kept at 5 metres above low-water mark. The supply of the basin was commenced by letting in the water from the river, but it was found that the quantity of mud thereby introduced would render the clearing of the basin a very costly affair, and arrangements are being made to supply it with clear water from a special source.

Artesian Wells. — It was consequently proposed to

augment the supply of water by means of Artesian wells. The success obtained in boring for water in many places in the department of the Gironde was such as to encourage the administration to attempt this method. The experiment was therefore tried, and a boring made to a depth of 220 metres. Its yield is estimated at about 6 000 cubic metres per day, and two other wells will soon be commenced.

Locks. — Two locks with chambers put the basin in communication with the Garonne; the chambers are parallel and are separated by an intermediate wall 10 metres in thickness. The largest is intended for great paddle-wheel steamers and is 22 metres in breadth by 152 metres in length between the gates. The smaller one is 14 metres in breadth by 136 metres in length, and admits screw steamers and sailing vessels; a pair of gates divides this chamber into two, one of 60 metres, the other of 76 metres.

The aqueducts with sluice-valves for filling and emptying the locks are in the masonry of the chamber walls.

The surface of the lock-chamber floor is formed in the shape of an inverted arch, in order to buttress the chamber walls and to offer the greatest resistance to the under-pressure of the water.

On each side of the locks is a clear space of 25 metres in breadth with foot-ways.

Swing-bridges. — There are two swing-bridges for each lock; a bridge at each end, so that when one is opened to allow a vessel to pass, the other is closed and affords a communication for the traffic. The breadth of these bridges

is 8 metres. Each of them rests on a pivot set in the axis of the intermediate wall, where the support occupies a metre of each of the lateral walls. It has thus two wings, one on each side on the pivot; one of 28 metres for the great lock, the other of 20 metres for the smaller lock.

The frame is of sheet-steel and consists of two longitudinal girders double T form, 48 metres in length and varying in height from $2^{m},35$ at the ends to $2^{m},80$ in the middle.

Between these great girders there are thirty-two cross-beams connected by smaller girders and transverse ties.

Rotation machinery. — This apparatus is contained in a stone basin formed in the intermediate wall between the locks below the pivot of each swing-bridge. It is arranged in the following manner. A cylindrical drum, 5 metres in diameter by $2^{m},275$ in height, is attached to the parts of the bridge surrounding the pivot. Two horizontal sets of rollers are set between the sides of the basin and the drum, and serve to support and guide the drum when in motion. The pivot is fixed to the bridge and is in the centre of the drum; it is formed of a wrought iron shaft, $0^{m},30$ in diameter, and rests in a socket which is borne by the piston of an hydraulic press established on the masonry of the intermediate wall, and which raises the bridge from its supports and enables the flaps to be worked. A chain winds round the drum, and moves the bridge according to the direction in which the chain is drawn, either to bring it on to the intermediate wall, or to turn it across the locks; the two ends of the chain are moved by hydraulic pressure. In case

of accident a reserve machinery is provided, consisting of a toothed wheel and pinion fixed to the circumference of the basin; this apparatus is fitted to the bridge and can be worked by hand.

Lock-gates. — The working of the locks is effected by means of seven pairs of gates lined with sheet-iron, viz.:

Two pairs of ebb-gates and one pair of flood-gates for the great lock; three pairs of ebb-gates and one pair of flood-gates for the smaller lock.

Fifteen large sluice-valves are fitted in the aqueducts of the chamber and intermediate walls, to regulate the entrance and exit of the water from the basin or from the Garonne.

The movements of the gates and the sluices, as of the bridge are regulated by hydraulic pressure.

The working part of the machinery is worthy of notice. The two leaves are worked by a single hydraulic pressure engine, placed on the intermediate wall, and the motive power is transmitted from one bank to the other by a chain which serves to open and shut the gate; all the gates are furnished with similar machinery.

Channel of entrance from the river. — The lock open into the river by a bell-shaped channel 80 metres in length. The entrance at the lock end is 100 metres broad and at the river end 242 metres; the sides are furnished with slips inclined to 1/5 in the same manner as the bank of the port.

At the foot of these sloping sides, and for 75 metres

above and below the outlet of the channel, rows of piling are arranged so as to facilitate the movements of vessels.

Dry-dock. — This dock is capable of receiving the largest Transatlantic steamers, and is situated on the left bank of the basin, at a distance of about 180 metres from the locks. Its construction was commenced at the close of 1874.

The total length is 154^{m},80 in including 14 metres for the entrance.

The entrance chamber is 22 metres broad; the walls are vertical, and there are two recesses or chambers for the floating or caisson-gates, the sills of which are on the same level as the mitre-sills of the locks, viz. 3 metres below low-water mark.

The perimeter of the walls of the dry-dock is divided into benches by four horizontal banquettes of 1^{m},10 in breadth. These banquettes are connected with each other by eight flights of steps. The upper end of the dock joins the two side walls in the form of a semi-circle with a radius of 14^{m},45.

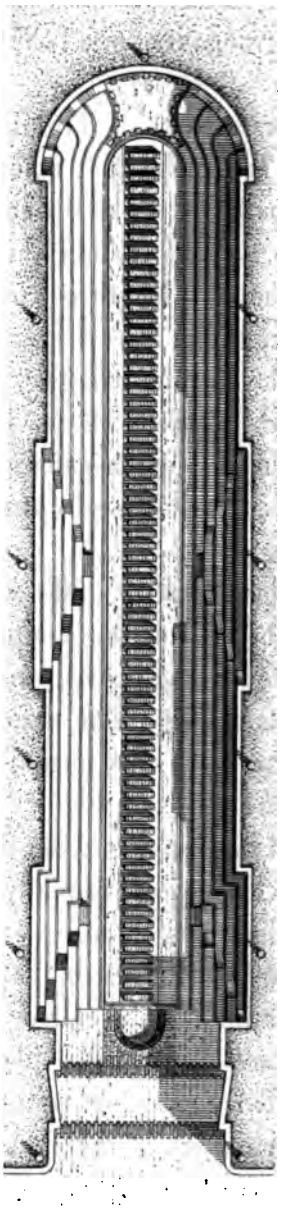
At the lower end the floor is 4 metres below low-water mark, and rises gradually towards the upper end with a longitudinal inclination of 0^{m},01 per metre.

The blocks rest on a platform in ashlar which occupies the middle of the floor, following the axis of the dock. On both sides of this platform, the transversal section of the floor has an inclination of 0^{m},01 per metre towards the water drains on each side at the foot of the walls.

A sheet-iron floating or caisson gate (*bateau-porte*) closes the dock on the basin side.

Dry-dock.

Longitudinal section.



Plan.

The filling and emptying of the dock will be effected by ans of three aqueducts terminating in a drain-well con-cted in masonry, the floor of which is $5^{m},70$ below low-er mark.

These aqueducts put the drain-well respectively in com-nication with the dock, the Garonne and the basin.

Their discharge is regulated by sluice-valves. The emp-g of the dock will be accomplished by means of steam-ps which will shortly be established in connection with drain-well.

Method of executing the works. — All the foun-ons of the works were laid by sinking hollowed blocks. al circumstances in the first instance necessitated the loyment of this method for the locks.

Foundations of the locks. — The ground consists of a r of argillaceous mud 12 to 14 metres in depth, beneath ch is a bed of sand and water-bearing gravel 3 or 4 me-thick, resting on a stratum of molasse or soft ter-y sandstone. The results given by borings established fact that the underground springs flow towards the Ga-ne, and exercise a considerable under-pressure on the nd.

n consequence of the level given to the mitre-sills of the s, the stone-work was laid entirely on the bed of sand. as impossible to entertain the idea of excavating to a th of nearly 14 metres in the soft mud, at the bottom which the water-bearing stratum was found; it was there-e decided to sink, by their own weight, a succession of

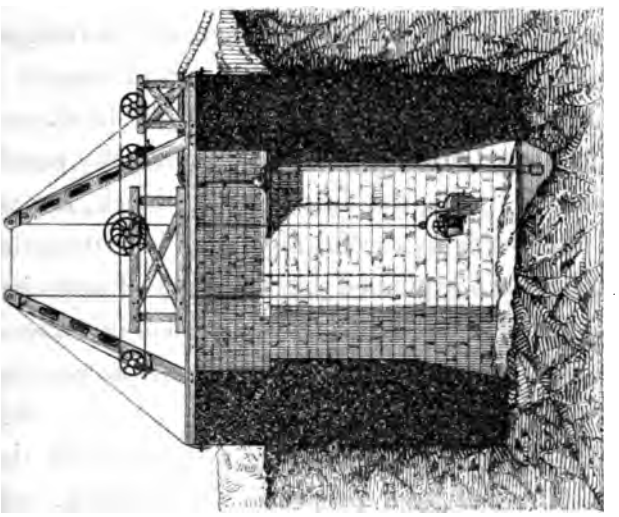
blocks of masonry down to the gravel in order to form the centre and side walls. These blocks occupied the perimeter of a rectangle 205 metres by 57.

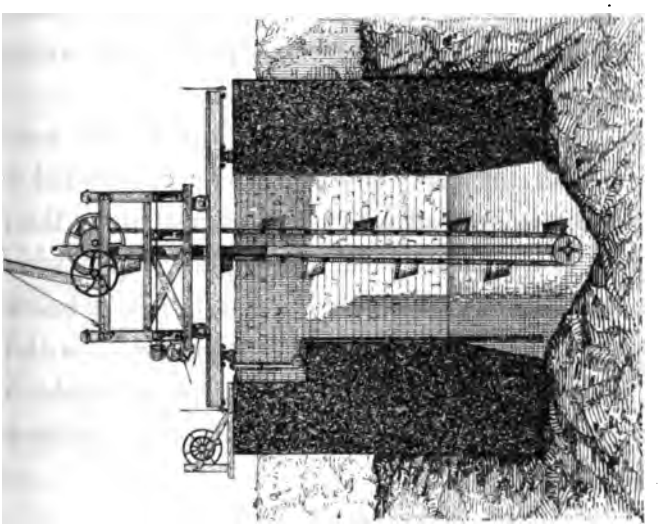
The blocks were shaped with a uniform breadth of 6 metres; their lengths varied from 16 to 35 metres with a height of 9 metres. Blocks of 9 metres broad by 15 metres long and 9 metres in height, were laid on the lower or down-stream half of the wall separating the two locks. All these blocks were placed at a distance of $0^{m},50$ apart, and hollowed out so as to present one or more vertical shafts.

The stone-work of a block was only carried up to half its definitive height, in the first instance. When it was well set, the ground was cleared at the bottom of the shafts and the block descended until its upper surface was on a level with the soil. The remainder of the stone-work was afterwards added in one or two courses, and sunk in a similar manner.

This operation was effected without the aid of machinery of any kind, so long as the progress of the work was not impeded by water. But the water made its appearance in the shafts when there remained only about 2 metres of the layer of mud to be penetrated, and it became necessary to establish in each shaft, a centrifugal pump worked by a movable steam-engine, which latter was at the same time utilized for working the winches bringing up the rubbish cleared from the bottom. The clearing was in this manner carried on without difficulty, and the operation of sinking was stopped when the block of masonry had penetrated $0^{m},80$ in the gravelly sand.

The work did not however always proceed with perfect





regularity, and frequently the blocks inclined more or les to one side, in spite of the props employed to steady them In general however, it was found possible to readjust them either by skiful management of the excavations, or by a lat eral pressure, effected by banking up the block on the sid to which it inclined. Sometimes this difficulty could not b surmounted during the descent of the block, but was rem edied afterwards by careful digging. These irregularities i the sinking are explained by the want of homogeneity i the nature of the ground; the numerous obstacles encoun tered, such as trunks of trees, etc., and the cavities cause by pumping.

The various difficulties being overcome, all the block were established in a perpendicular position, with som slight deviations in the ground plan, which were correcte while finishing the facings of the chamber walls.

When the sinking of the blocks was completed, the shaft were filled in with beton for the part below water, an with stone-work for the upper portion.

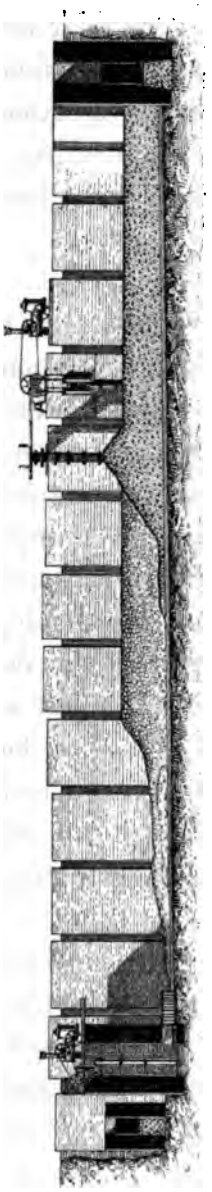
The intervening spaces between the blocks were als filled in with masonry, and the whole constituted an en closure, the interior of which was excavated by the aid o pumping, down to the level of the gravel upon which th invert or floor was constructed dry, at 7 metres below low water mark; the work was afterwards proceeded with in th usual manner. At the present time it has attained a heigh of 4 metres above low-water mark, and is perfectly water tight in every part.

Foundations of quay walls. — The successful re

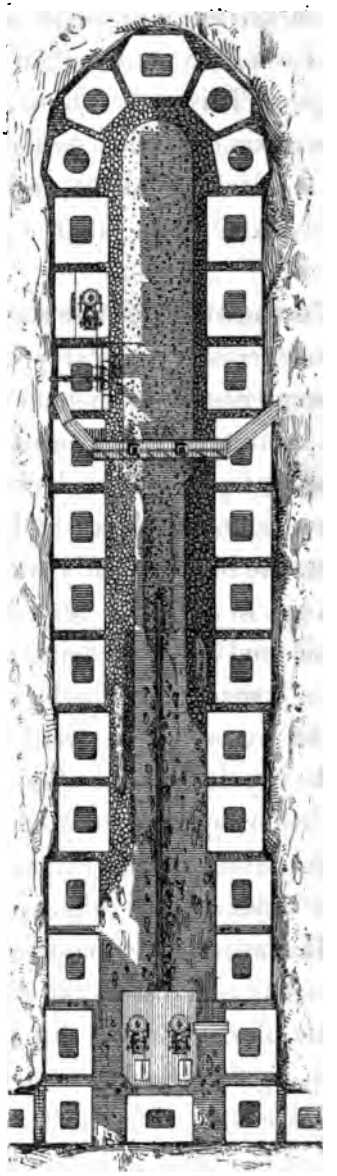
sult of the system employed in laying the foundations of the locks, encouraged its application to the quay walls of the basin, the construction of which had been commenced on piles. This wall is built, for two-thirds of its extent, on a succession of semi-circular arches of 8 metres span, resting on blocks, 6 metres in length and 5 metres in breadth, and sunk 1 metre into the gravel.

Foundation of the dry-dock. — The extent to which it was necessary to carry on the pumping operations, in consequence of the manner of sinking the blocks, which has just been described, caused the foundation ground to settle in several parts of the locks and the adjoining surface. In some instances, these accidents were sufficiently important to put the blocks greatly out of the perpendicular during the sinking. In order to remedy this defect, the pumping was abandoned and a dredging machine employed. This method did not succeed at the locks, owing to the peculiar nature of the ground and its want of homogeneity; but in the case of the dry dock it was otherwise, and the borings previously made having demonstrated that these difficulties would not be encountered, the excavation by dredging was employed with satisfactory results.

The experience acquired in laying the foundations of locks has established the utility of increasing the thickness of the blocks and the distance between them, as well as of reducing their length in order to graduate the sinking and facilitate their subsequent union. The knowledge thus acquired has been turned to account in modifying the dimensions of the blocks in the following proportion : the blocks



Foundations of the dry-dock.



of the dry-dock have a thickness of 8 metres instead of 6, like those of the locks; their extreme length is 11 metres, while some of the blocks employed in the construction of the locks are 35 metres; and lastly, the space between them is 1 metre, instead of $0^{m},50$ as in those of the locks.

Of thirty-six blocks used in the foundation of the dry lock, twenty were sunk by means of a dredge with a vertical hoist, and sixteen by pumping.

In forming the foundations of the dry-dock, the advantages of dredging were found to preponderate considerably over those of pumping. For example, an average time of one hundred and ten hours only was required to sink, with the dredge, blocks of which the sinking by pumping occupied 1 month. With regard to the cost, the work accomplished by means of dredging was done at a rate of $7^{f},35$ per cubic metre of displacement, while the work done by the use of the pumps cost $11^{f},95$ per cubic metre of displacement.

Nature of the materials employed and the localities from which they came. — Piles for the piling: pine from the Landes.

Granite for crowns, quoins, mitre-sills, angles of gate-chambers: from the Labère quarries (Finistère).

Hard ashlar and calcareous rubble: from the Saint-Macaire quarries (Gironde).

Slowly setting cement: from Portland (England).

Hydraulic lime: from Theil (Ardèche).

Hydraulic lime: from Saint-Astier (Dordogne).

Iron and steel: from the Creusot works.

Cost. — The outlay authorized for the construction

of the Bordeaux basin may divided under the followi heads :

Purchase of land	2 968 769f,55
Basin, locks and dry-dock (earth-work and masonry)	9 959 076 ,03
Iron-work (lock-gates, sluices, swing-bridges, floating-gate, dredging boat, hydraulic engine)	1 624 621 ,71
Excavations, dredging and enrockments for the river entrance	387 436 ,42
Frame piling for the river entrance	35 007 ,80
Paving	711 781 ,66
Artesian well	60 430 ,57
Dock buildings	83 433 ,44
Contingent expenses	1 035 925 ,06
TOTAL	16 926 482 ,24

Of this sum there was expended, up to the 31st Decemb 1879 :

For purchase of land	2 968 769f,55
Works	13 524 084 ,06
TOTAL	16 492 853 ,61

Allotment of the contracts and situation of tl works therein specified. — The works for the co struction of the basin, locks and dry-dock, included in o contract, were allotted to M. BERNARD junior. They a nearly completed.

The second contract included the lock-gates, sluice swing-bridges, dredging-boat and hydraulic machinery, a was adjudged to MM. SCHNEIDER and Co of Creuzot.

These works were finished and put in position towards the close of 1879.

The river entrance and the paving constitued two distinct undertakings; MM. Avril and Fréland were the contractors for the one, and MM. Dufour and Couture for the other. These works were also finished towards the close of the year 1879.

The dock buildings were the subject of a special contract and were allotted to M. Gustave Dalibon. They were finished in October 1879.

The preliminary survey of the Bordeaux basin was made up by M. Joly de Boissel, as engineer, under the orders of MM. Droëling and Pairier, engineers in chief.

The engineers who assisted in preparing and carrying out the definitive plans of the work are MM. Joly de Boissel, engineer in chief, de la Roche-Tolay, Regnauld and Boutan, engineers.

M. Fargue, engineer in chief, was appointed to the direction of the service, in December 1879, and superintends the finishing of the work.

The conducteurs entrusted with the preparation of the plans, specifications and overseeing of the works were or are MM. Groult, Pochet, Pardiac, Bert, Potocki and Aché (Oreste).

XIII

PORT OF SAINT-NAZAIRE.

(DEPARTMENT OF THE LOIRE-INFÉRIEURE.)

I. General description of the port.
II. Penhouët basin. — Foundations of quay walls.
III. Iron lock-gates,

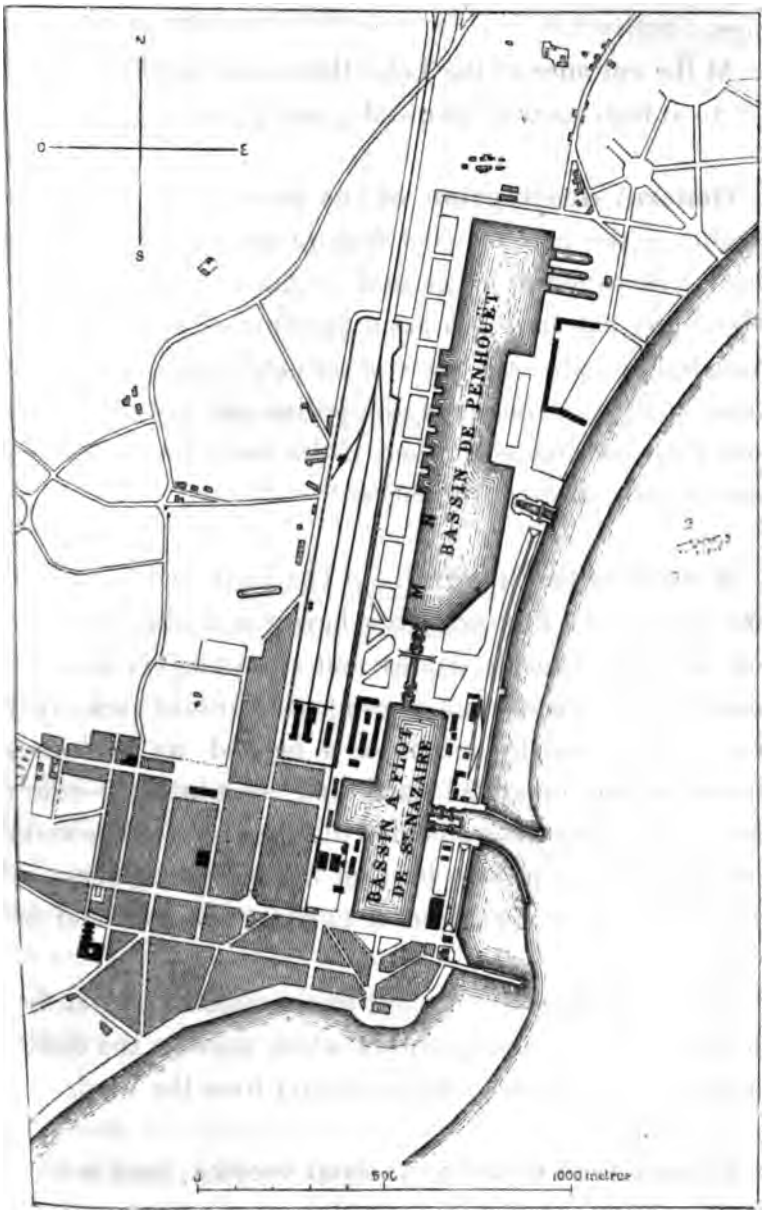
Bird's eye view of the port and town.

I

GENERAL DESCRIPTION.

The port of Saint-Nazaire is situated on the right bank of the Loire, at the mouth of the river, and is but of recent creation. Thirty years ago, the spot now occupied by the basin was only a small creek or bay, frequented by pilot and fishing boats.

In front of the port is a roadstead, formed by a vast widening of the great channel of the Loire. There is a depth of 8 to 15 metres at low water, and the bottom being composed exclusively of mud, vessels find excellent holding ground in this roadstead. There is very little swell, and the smoothness of the water is owing to the rocks and sand-banks at the mouth of the river, which break the force of the waves. The mole, constructed at the point of the old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town, also contributes greatly to the security of the anch rage.

At the entrance of the Loire there is a depth of a lea $7^{m},70$ at high water of neap-tide, and $9^{m},20$ at spring-tid

General description of the port. — In its prese condition, the port of Saint-Nazaire consists of a chann lined with wooden jetties and terminating in two loc which give entrance to a basin surrounded by quays. Th roadstead supplies the place of an outer port, and vessel moor at the extremities of the jetties and are afterward towed up the channel; when if the basin be open, the pass directly through the locks.

Nature of the ground. — The basin and locks ha been established in a small bay having a mud bottom, b low which at variable depths, but always higher than t foundations, is a stratum of compact schistous rock. Th were constructed by means of a banked up enclosur formed of the excavated earth and constituting a coffe dam. Many difficulties attended the execution of this wor but the talus, 4 in base by 1 in height, strengthened l stone-packing, has enabled it to resist the action of t water.

This embankment, enlarged by the rubbish excavated the basin, forms an earth-work which answers the doub purpose of fortifications and of shelter from the wind.

Dimensions of the principal works, and heig of the tides. — Before entering into details, it will l

eful to furnish these particulars. The heights of the tides e given in relation to the general level of the port:

Crown of locks and floor of jetties	13m,60
Crown of quays of the first basin, called the Saint-Nazaire Basin	14 ,50
High water at equinoctial spring-tide	15 ,08
High water at ordinary spring-tide	15 ,50
High water at neap-tide	17 ,00
Low water at neap-tide	19 ,30
Low water at ordinary spring-tide	20 ,50
Zero of *Annual of tides*	20 ,83
Low water at equinoctial spring-tide	21 ,00
Zero of Saint-Nazaire gauge	21 ,10
Mitre-sill of lock 13 metres broad	23 ,10
Bottom of south part of Saint-Nazaire Basin	23 ,20
Bottom of north-west part of Saint-Nazaire Basin.	24 ,00
Mitre-sill of lock of 25 metres in breadth (lock between the two basins, at the same depth)	24 ,30
Bottom of north-east part of Saint-Nazaire Basin.	24 ,50
Carpenters' bar	24 ,73

Channel. — The channel was opened through a bank mud, which at high tides is found as far as the end of the uth jetty, and on the north bank, extends to a distance of enty metres behind the wing-wall of the lock, where at w water there is always a depth of 2 or 3 metres.

It is deepened and dredged so that ships always find metres of water at high neap-tide.

Jetties. — Wooden jetties extend along the two banks of the channel. The uprights are 3m,75 apart from centre to centre, and have an exterior batter of one tenth.

The flooring is $4^m,50$ in breadth, reduced to $3^m,36$ between the side-rails. It is on a level with the crowns of the locks, and $1^m,48$ above the equinoctial tides.

All the wood-work is in Prussian pine. The teredo worm, which formerly was not known at Saint-Nazaire, made its appearance there, in 1859. Its ravages have been very considerable.

In every part joining the lock, it was necessary to establish the north jetty on layers of thin mud, which reach a depth of several metres below low tides, and rest on a very hard rock into which piles could not be driven.

The method adopted for this part of the foundations was the same as that previously employed for the walls built in extension of the side-walls of the locks. The uprights were fixed in blocks [1] of stone-work 6 metres square, carried down to the rock by their own weight, the mud being taken out from the inside [2]. These shafts, levelled to the depth (18 metres), received the soles of the uprights.

This mode of construction has succeeded very well. Carried to perfection by the employment of compressed air, it has been successfully used in the foundations of many great bridges and similar works, where the defective nature of the ground presented extraordinary obstacles.

[1] It has been found absolutely necessary to translate the word «puits», which ordinarily signifies *shaft* or *well,* by the word «block», indicating in this case, a mass of stone-work with a shaft or hole in the centre. The word *shaft* alone, would lead to confusion, and *shaft-block* is open to objections. Engineers will find no difficulty in comprehending the signification conveyed, but the ordinary reader would be completely mystified. (TRANSLATOR.)

[2] The details of these blocks may be found in the *Collection of drawings of the École des Ponts et Chaussées,* vol. I, p. 295 to 301.

Locks. — Two locks occupy the channel and have ıeir foundations entirely upon the rock. The largest, conructed with the view of admitting Transatlantic paddle-steam-'s, is 25 metres in breadth. It is a simple lock with two ıirs of gates, of which one pair can serve in case of accidents · repairs. At the lowest point of the mitre-sills, which take ıe form of an arc of a circle raised $2^{m},50$ on the sides, there $7^{m},30$ of water at the lowest high tides, and at spring-de $8^{m},80$.

The small lock is 13 metres in breadth, and has a cham-ɜr 60 metres in length, capable of being used from half-ɔod till half-ebb, that is to say, six or seven hours. The ıitre-sills are horizontal, and the tide rises from $6^{m},10$ at eap-tide and $7^{m},60$ at spring-tide.

When a large ship requires to enter or leave the basin, ıe lock of 25 metres can remain open two or three hours.

Basin. — The locks terminate in the middle of the basin, he dimensions of which are as follows:

1st part.	Length	580^{m}
	Breadth	160
2nd part.	Length	140
	Breadth	90

The superficies is $10^{h},40$.

All the lower part has been excavated to a variable depth in schistous gneiss which, simply covered at certain points with a facing in masonry, forms the body of the quay walls.

The depth of water maintained in the basin is always

equal to or greater than that of the lowest flood at neap-tic (17 metres). The following depths are found at this level

Opposite the locks and the Quay des Frégates....	7m,50
The length of the Quay de la Marine.....	7 ,10
Between the Quays of the Loire, Vieille-Ville and Commerce.....	6 ,20
Between the Quays Watier, Henri Chevreau and Jégou, from 6m,20 to.....	7 ,00

The basin is surrounded by vast quays connected wit the railway terminus by lines of rails.

The port of Saint-Nazaire being especially a port c transit, almost all goods pass directly from the vessels int the trains, or into lighters which go up to Nantes, and vic versa.

The total length of the quays is 1 580 metres. A gre part of this space is occupied by the public services and th General Transatlantic Company. The lands situated behir the Marine and Jégou quays have been granted to this Cor pany, and sheds, stores, work-shops, coal-yards, etc. ha been established, containing all things requisite for the se vice of the Company's two lines of Mexico and the Antille

The 860 metres of quays which had been allotted commerce are now utterly inadequate to its requirement and the completion of the second basin is looked forwa to with impatience. It will, in all probability, be opened f traffic in the month of October 1880.

Clearing the port of mud. — By referring to t commencement of this notice, it will be seen that t

channel of the port of Saint-Nazaire was opened through the middle of a bank of mud, which is constantly being renewed by the tidal deposits. It was necessary to act promptly in this matter, and the problem was solved in a manner at once satisfactory and economical, by the aid of pumping and discharging boats, the same engine working successively both pumps and propeller[1]. This boat was taken to a distance of 1 000 or 1 500 metres from the port, and there discharged by opening the valves.

An ordinary dredging-machine with buckets is sufficient for those parts of the port where, for various reasons, the mud is not sufficiently liquid to admit of being pumped, which is the case when the density exceeds 1200.

At the present time the importance of dredging operations and the cost attending them are accurately known. To maintain the normal depth of water, required for the movements of large vessels, it is necessary to remove the following quantities every year :

In the basin (from a superficies of $10^{h},40$)..	163 000^{cm} of mud.
In the channel (from a superficies of $1^{h},35$)..	193 000
TOTAL.....	356 000^{cm} of mud.

Which is equal to $1^{cm},55$ per square metre of the basin, and $14^{cm},27$ per square metre of the channel.

Three fourths of this mud is pumped, the remainder is dredged.

[1] See detailed description of this dredging boat in the *Collection of drawings of the École des Ponts et Chaussées*, vol. I, p. 34.

These operations are carried on at the following cost per cubic metre, for pumping and discharging :

COST PER CUBIC METRE OF MUD PUMPED.

Coals, repairs and labour	0f,18
Interest and payments for working material	0 ,24
TOTAL COST	0f,42

EXTRACTION AND DISCHARGE OF MUD DREDGED.

Coals, repairs and labour	0f,38
Interest and payments for working material	0 ,37
TOTAL COST	0f,75

These expenses of maintenance amount to about 80 000 fr. a year.

Expenses. — The cost of the works of the Saint-Nazaire Basin may be divided as follows :

Enclosure dam	295 000f
Earth-works and masonry of basin	5 424 000
Construction of jetties and excavating channel	1 434 000
Lock-gates, sluices, etc	693 000
Various works	280 000
TOTAL	8 126 000f

New works in course of construction or planned. Penhouët Basin. The inadequacy of the basin at Saint-Nazaire was soon ascertained, and it was decided that a second basin should be formed in the bay of Penhouët. The cost is estimated 22 800 000 francs, and

this time the works are being prosecuted with the great- activity.

It was impossible to form a direct entrance from the dstead to the Penhouët Basin. To attain any great pth, it would have been necessary to advance conside- ly into the open and deep water, and the projection asioned by the formation of a new channel, would have llibly silted up the present entrance. Under these cir- nstances, it will be necessary to enter the second basin passing through the first.

The circular embankment that surrounds and protects the work-shops, was finished in 1865, and is now being arged with the soil excavated from the basin.

Lock-chamber. — The communication between the basins will be effected by means of a lock-chamber, sim- to the present lock, 25 metres in breadth, and $7^{m},30$ depth of water, at neap-tide on the sills, which are hori- tal.

Four pairs of gates[1] will enable the lock to be worked in h directions, in order to ensure perfect control of the el of the water in the Penhouët Basin, and to prevent accumulation of mud there. The length of the lock- amber is 130 metres.

Two large culverts 2 metres in breadth pass through the hole length of the chamber walls and connect the two ba- ns. They serve for working the lock-chamber with which ey communicate by means of subordinate culverts. Heads

[1] See description of these gates, chap. III of this notice.

of water have been created, passing through small culverts with outlets $0^m,20$ in height, level with the bottom of the gate-chambers. They will serve to produce rapid discharges of water, and will obviate the necessity of clearing out the mud by hand labour.

An iron roller-bridge for carriages and general traffic will be constructed at the middle of the lock.

The lock is finished and, until the completion of the second basin, will serve as a dry-dock for the large mail steamers. For this purpose, large pumping engines have been established close to it, and will be afterwards available for the three dry-docks situated on the north of the new basin.

Quay walls. — It will not be possible to build wall all round the basin. The precarious nature of the subsoil will not allow their construction in the mud valley which crosses the basin. At the south-east angle and the middle of the west quay, stone-packing, resting on large enrockments is substituted for them. Wooden platforms enable vessels to come alongside the quays.

The quay walls are $10^m,40$ in height above the bottom of the basin, and are founded upon the solid rock, but under varying conditions. While some parts are composed of simple stone facing, others have been carried to a depth of 15 and even 18 metres below the bottom of the basin in order to reach the rock. In this latter case, they were constructed on a vaulting, and the piers founded by means of shafts similar to those of the North quay [1].

[1] See detailed description of this method of construction, chap. II of the present notice.

Three dry-docks, also founded on the rock, are established in the basin of Penhouët. The following figures give their dimensions.

DOCK.	BREADTH of ENTRANCE.	LENGTH.	DEPTH below high water at neap-tide.
N° 1	25m,00	140m,00	7m,30
N° 2	13 ,00	120 ,00	4 ,50
N° 3	18 ,00	150 ,00	7 ,30

N° 1 dock is now finished. The two others will be completed at the end of the year and N° 3 will be reserved for the Transatlantic service.

Head of water. — In creating at Saint-Nazaire a second basin more than double the size of the first, the reduction of the accumulation of mud to the lowest proportions, became an imperative necessity.

With this view, a special head of water from the roadstead will be discharged by means of sluices. These will not be worked more than two or three times a month, and always in calm weather, when the upper part of the water is not heavily charged with mud.

The head of water will be 26 metres in breadth, and the sluices will be worked by lowering, in such a manner as to take only the surface water to such a depth as may be deemed convenient. The working of these sluice-paddles, as also those of the communication lock and of the roller-

bridge, will be accomplished by machinery moved by h draulic pressure.

Building-yards. — Between the basin and the roa stead, sufficient space has been reserved to establish buil ing yards. One part is already taken up by the Gene Transatlantic Company, and five of their great iron m steamers have been constructed there.

Cost. — The cost of the Penhouët Basin was estimat at 22 800 000 francs, divided as follows :

Purchase of ground	1 775 000f
Circular embankment	600 000
Earth-works	4 700 000
Lock, 25 metres in breadth	3 500 000
4 pairs of iron gates	1 000 000
Quay walls and stone-packing inside the basin	5 800 000
Roller-bridge, head of water and hydraulic machinery	800 000
Three dry-docks	3 000 000
4 floating gates for these docks	700 000
Various works	325 000
Use of lock as temporary dry-dock	100 000
General and unforeseen expenses	500 000
TOTAL	22 800 000

The engineers who have successively assisted in the pla and excution of the works of the port of Saint-Nazaire, a MM. CABROL and PLANTIER, engineers in chief, directo A. JÉGOU, CHATONEY and DE CARCARADEC, engineers in chi

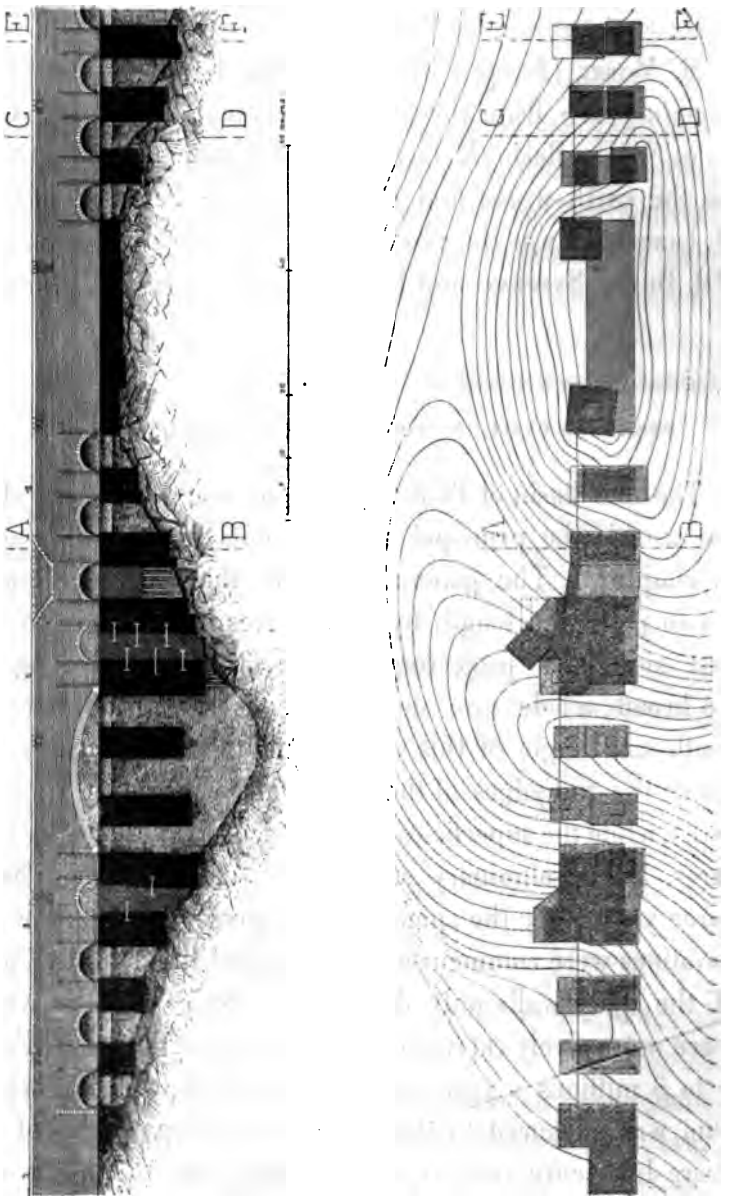
DE LA GOURNERIE, A. WATIER, LEFERME, RÉVOL and POCARD-KERVILER, engineeers « des Ponts et Chaussées ».

M. MOREL (Joseph) has ben attached to these works as « conducteur » from their commencement, for the first or Saint-Nazaire Basin; M. DAVID was the principal « conducteur » for the earth-works and masonry of the Penhouët Basin, M. LABUSSIÈRE was the « conducteur » for the dry-docks, and MM. BUTAT, STEPHANY and LE GAL, for the iron constructions.

II.

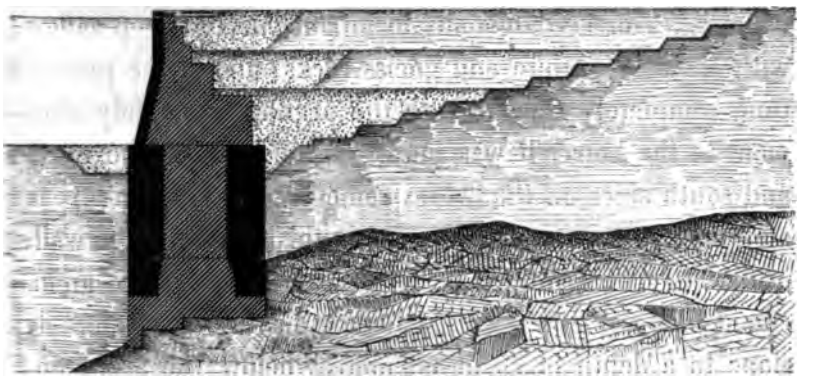
PENHOUËT BASIN. — FOUNDATIONS OF THE QUAY WALLS.

The new basin of Penhouët will be one of the largest in the world; the principal arrangements have been shown in chapter I. The general form is that of a rectangle 1100 metres in length by 230 metres in breadth; on the east side is a projecting redan, 300 metres long by 70 broad; a side 200 metres long is substituted for the south-east angle of this redan, and the total surface between the top edges of the quay walls will be 22 1/2 hectares, while the superficies of the present basin is only 10 hectares. The preliminary survey was sanctioned in 1860, three years after the opening of the present basin. The excavations were commenced in 1869, but the definitive plan of the quay walls only dates from 1875, and the works were not actively carried on till the close of that year. From 2 to 3 millions a year were appropriated to them, which sum was advanced to the State by the department of the Loire-Inférieure, and it is anticipated that the works will be completed in October 1880.

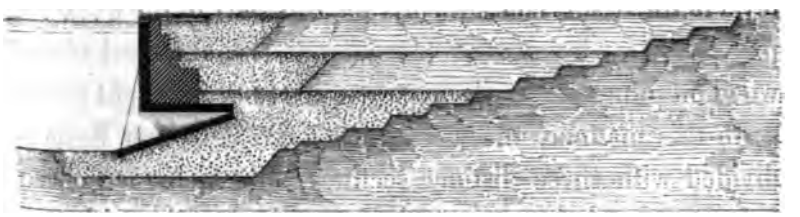


Part M N of the West Quay.

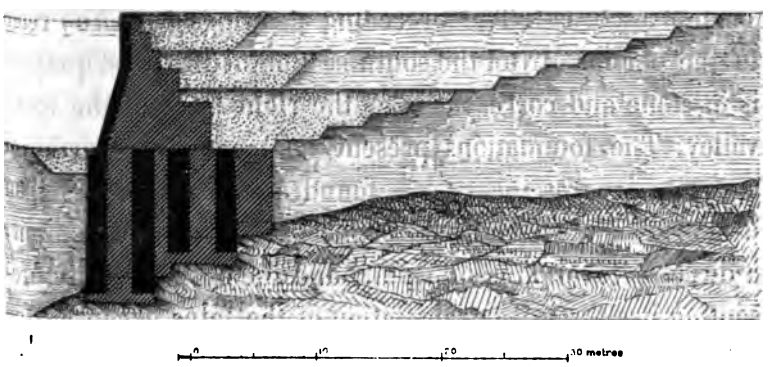
Section A B.



Section C D.

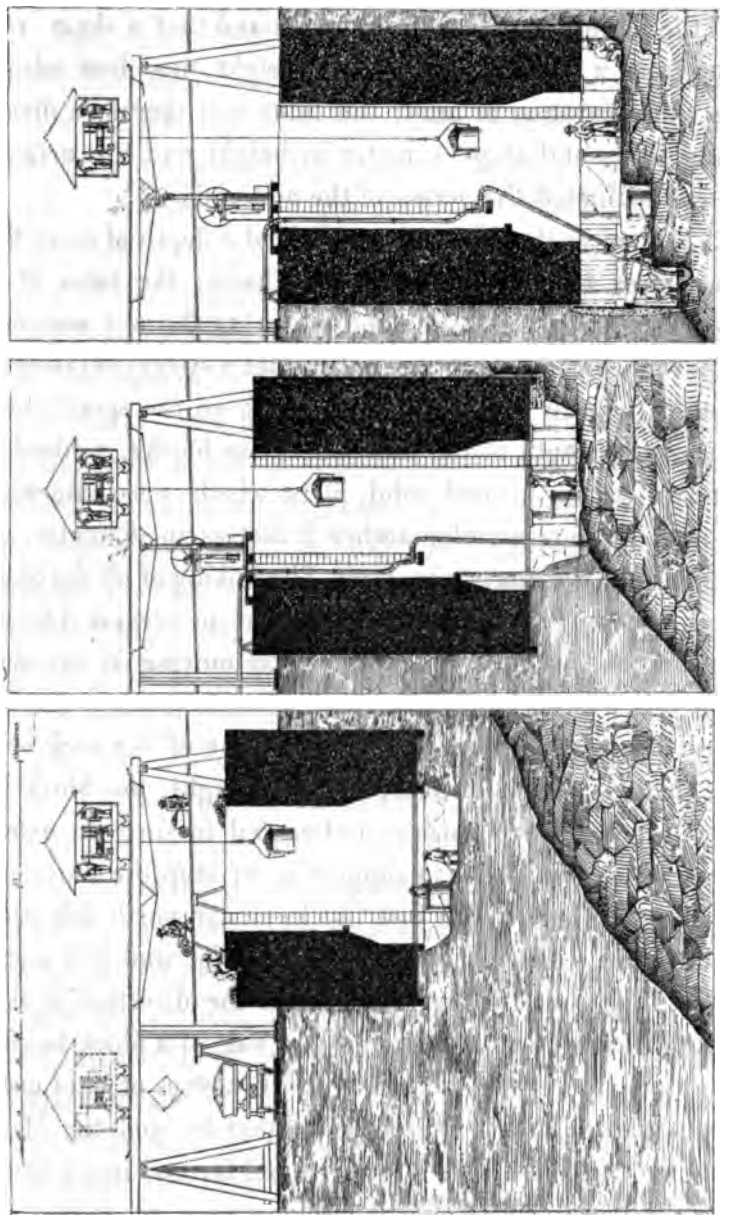


Section E F.



The topographical situation of the ground necessitated these vast dimensions. The space covered by the Penhouë Basin is traversed diagonally by an ancient and deep valley with sides of granite and gneiss rocks, and at the presen time completely filled up by the argillaceous sandy allu vions of the Loire. It was necessary to establish the nortl and south sides on the two extreme banks of this valley. I approaching the water-course in both directions, the wall of the quay were obliged to be sunk on the length of an in clined plane of hillocks or declivities, having a considerabl slope to a depth of 15 or 18 metres below the bottom o the basin. Near the water-course itself, it would be necessar at certain points, to reach a depth of 30 metres below th level of the basin; consequently for this part of the work th plan of vertical stone quays was abandoned, and stockades o wood on piling were adopted, capable of bearing light goods

In this manner, the west side of the Penhouët Basin i divided with three distinct sections, of which each of th two extreme divisions is 356 metres in length, with ver tical stone quays, while the central section is 388 metre in length, and has six stockades or rows of timbers, eacl 12 metres broad. The preceding drawings (p. 140) refe to the portion MN of the south section of this west quay; i is in stone and corresponds to the right bank of the rock valley. The foundations present no peculiarity worthy o notice so long as the rock is found at a depth of less tha 4 metres below the bottom of the basin. Within this limit a direct excavation is sufficient, and the only difficulty pre senting itself is in the calculation of the talus necessary fo clearing away the alluvions.



Sinking of a block.

In these conditions of depth (10 to 14 metres) and fixity of the bottom of the talus, it was found that a slope, varying from 2 to 3 of base for 1 of height, was best adapted to the excavation of mud; the talus was therefore divided into horizontal steps 1 metre in height and this arrangement facilitated the access of the materials.

As soon as the excavations attained a depth of more than 4 metres below the level of the basin, the talus of the work possessed so little stability during the wet seasons of the year, that it was necessary to adopt a system of laying the foundations by means of blocks sunk on the spot through the entire depth of the alluvion; these blocks, wedged up and filled in, formed solid piers which were afterwards united by semi-circular arches 6 metres in diameter, and upon these the quays were built. The sinking of all the blocks was done in the open air, and offered no serious difficulty so long as the block of masonry was moving in the mud; but this was no longer the case, when it touched the rock with one its sides or angles. The slope of the rock being frequently 2 or 3 of base, for 1 of height, the block lost its perpendicular bearing, and canted to such an extent, that it was impossible to support it, or stop the movement of the mud below. The first blocks on the north side had a section of 11 metres by 5, with an interior void of 5 metres by 2. The slope of the rock was in the direction of their length, consequently when the west side of a block touched the rock, there was still a depth of 6 metres of mud under its east side. It was therefore decided to sink the blocks into the rock itself, when levelled and formed into a bed to receive them; and this difficult operation constituted the

novelty of the method which was carried out as in the following brief description :

When the block touches the rock on one of its outer sides (see the series of drawings representing the successive phases of the operation) large piles $0^m,40$ to $0^m,50$ square are driven in along the length of the opposite inner side; they are then sawn off to $1^m,50$ or 2 metres above the lower platform of the block, and by means of hydraulic screws, they are brought under a cross-beam embedded in the masonry. The mud is then excavated to a depth of $1^m,50$ below the blocks, and by means of the pick, or blasting, a triangular mass is broken from the rock, and a horizontal face is left. As the work progresses, the block is steadied by heavy logs placed under it, and when the broken rock is cleared away, a hole is bored with an auger half-way through each of the logs, and in each of these horizontal holes is put a charge of 50 grammes of dynamite with an ordinary fuze 1 metre long; the fuzes are lighted, all hands ascend the shaft, and the explosion shatters and crushes all the logs. The block of masonry then descends and breaks either the large piles or the cross-beam which has not been subjected to the blasting force, in order to preserve a resistance on the mud side. This resistance and the bed of mud which is pressed down, cause the descent of the block to be regular and vertical. The operation is then recommenced in a similar manner $1^m,50$ deeper, by detaching, this time, a trapezoidal mass of the rock, and from depth to depth the work proceeds, till the block is deposited in a bed of rock of which the base is horizontal and the surface sufficiently large to preclude all fear of its deviating from the

perpendicular, and to enable the remaining mud to b cleared out without being obstructed by the syphonal actio of the external deposits.

In this manner the great shaft abutment was sunk i three successive operations, through 4 metres of rock. It 9 metres by 12 square, and weighed 2 000 000 kil grammes; in the last stage of the descent it was stayed l twenty-five props $0^{m},45$ square, and twenty miners worke beneath it in perfect security.

In order that the sinking might be easier and more ec nomical, it was resolved to divide the foundation blocks in two and to range one behind the other, when the soun ings indicated that the slope of the rock was too steep. I this way, there were fewer descents, and a smaller cube rock to cut away, and when the two blocks were secure underneath, it only remained to clear out the space betwee them down to the solid rock, and fill in with masonry. B this system has its drawbacks; in the first place the bloc are much lighter, and do not sink so well on account of t lateral friction of the layers of mud and it is frequently n cessary to weight them with 80 or 100 tons of pig-iron start them; besides this, the block in the rear, thrust fo ward by the difference in the pressure of the excavated stu is drawn towards the block in the front to such a degree th it sometimes becomes very difficult to clear out the inte mediate space. The two blocks being 5 metres by 5 metr square and the space between them 2 metres, it almo always happens that they approach each other at lea 1 metre while sinking from 10 to 15 metres in the mu

To bring up the excavated stuff and work the pumps

the same time, it was found advantageous to employ a travelling winch worked by steam, and the necessary movements were obtained by means of ropes made of iron wire and hemp twisted together.

Notwithstanding the exceptional difficulties to be contended with, and the frequent fallings in of the talus excavations; notwithstanding the continued syphonal action of the lower layers of mud inside the blocks, the work was executed at a moderate cost. The outlay per cubic metre of the pier masonry, including all expenses and the carriage of the excavated rubbish to a distance of 1 kilometre is divided as follows, according to an average of 35 000 cubic metres of the foundation executed under inspection and now finished:

Masonry...	Materials.	Ordinary rubble with 400^{k} of cement mortar for the block, and mortar with one third of hydraulic lime for the filling in masonry.....	19^{f},00
	Work, all obstacles and loss of time included.....		10,00
Hoisting machines for excavations			3,00
Excavations (it was necessary to clear out about three times the cube of the pier on account of the fallings in and the syphonal action).....			14,00
Carriage of excavated rubbish to a distance of 1 kilometre.....			4,50
Pumping.....			3,00
Timber for platforms, piles, shores, etc.....			2,00
General service.....			1,50
TOTAL cost per cubic metre...			57^{f},00

This sum is considerably less than the cost of most tubular foundations.

The preliminary surveys were made by M. Leferme, engineer, under the direction of M. Chatoney, engineer in chief.

The final plans were drawn and the works directed by M. Pocard-Kerviler, engineer, under the direction of M. de Carcaradec, engineer in chief.

M. David assisted in this work as principal « conducteur ».

The contractors were, M. Bord, for the masonry and general earth-works, MM. Buette and Béchu, civil engineers, for the working machinery, under inspection, and MM. Hermann-Lachapelle for the construction of the machines.

III

IRON GATES OF THE LOCK 25 METRES IN LENGTH CONNECTING THE TWO BASINS.

The first pair of gates (with two leaves lined with wood), of the 25 metres lock, which connects the two basins, was planned in 1869 and constructed from 1873 to 1874 by the Ocean Company.

The horizontal section takes the plano-convex form already adopted for the wooden and iron gates of the great entrance lock of the Saint-Nazaire Basin. This form approximates, as nearly as is practically possible, to a section of equal resistance, suitable to a beam supported at each end and equally weighted along its whole length. On the other hand, the curvature in the middle prevents the gate from giving way under the longitudinal pressure produced by the

meeting or abutting of the two leaves. The curve of the side has the same centre as the circle described at the mitre-sill.

Accordingly the general dimensions of the leaf are was follows :

Plane side in elevation.	Height	$10^{m},202$
	Breadth	13 ,697
Plan of the gate.	Thickness at the ends of the leaf.	0 ,600
	Rise on the middle of the leaf...	1 ,623
	Radius of the circle of the curve..	24 ,050

The method of construction was combined in conformity with the experimental investigations of the late M. Chevallier, Inspector general, and the calculations of M. Lavoinne; cross-pieces at equal distances apart, were employed, always taking into consideration the resistance of the vertical pieces uprights and skin.

In accordance with the principles laid down by these two engineers, the first thing to be done was to reduce the cross-pieces to the lowest number, practically possible, that is to say by using for these cross-pieces only sheet and angle-iron of ordinary manufacture.

It was decided to employ twelve cross pieces $0^{m},897$ apart from centre to centre. Considerations of a similar nature led to the adoption of five vertical pieces : one in the middle, following the transversal axis of the leaf, two others at each quarter of the length in plan, the two last are at a slight distance ($0^{m},66$) from the two faces. These two last may be considered as dependencies of the tubular systems with form the mitre-posts and heel-posts; so that

from this point of view the gates only present three vertical pieces, in addition to the heel and mitre-posts.

The cross pieces, like the vertical pieces comprise : a web of $0^m,015$, of which the double T is formed of a band $0^m,335 \times 0^m,015$; a skin of $0^m,010$, and angle-irons $\frac{0^m,110 \times 0^m,160}{0^m,016\ 1/2}$. Their moment of inertia is 0,0253.

The formulas of M. Lavoinne were applied throughout for calculations of resistance of the pieces, and the verification of their dimensions. The coefficient of general rigidity for the leaf was fixed at 2,13, and it was found that the iron should not be subjected to work of more than 4 kilogrammes per square millimetre, either in the cross-pieces or vertical pieces.

The skin $0^m,010$ thick only works to 1/3 of a kilogramme per square millimetre; in adopting this thickness rust has been taken into consideration. The iron was not galvanized, it being feared that this operation would deteriorate it in quality. Neither was zinc sheathing employed, since the trials made did not appear to demonstrate sufficiently the advantage to be gained by its use.

For the preservation of the iron-work, painting was the only method practised, and the interior compartments of the leaves are so arranged that they can be scraped and painted when necessary.

In respect to stability, the fourth cross-piece forms a sort of air-tight bridge, so that the water has free play and the gate is protected against all chance of being raised by the force of the tides. In neap tides, the weight of each leaf, including the water let into the upper compartment, is 140 tons, and the upward or lifting strain is 120 tons. The

weight of the submerged leaf is 14 tons and at lowest neap tides, 15 tons; it is at no time below 10 tons in spring-tides.

In order to ensure the close shutting of the gates, an India rubber band is fixed to the mitre-sill, and three years experience demonstrates that the lock can serve as a temporary dry-dock. The various manœuvres are effected by means of hand-winches.

The total cost of the two leaves, with there accessories, amounted to 300 000 francs.

The plans were drawn by M. Révol, engineer, under the direction of M. Chatoney, then engineer in chief.

The works were executed under the direction of M. Leferme, engineer in chief, by M. Révol, engineer, assisted by M. Butat, « conducteur des Ponts et Chaussées. »

The contract for the iron-work was taken by the Ocean Company.

At the present time three pairs of gates of the same type are in course of construction for this lock.

The works are executed by M. Pocard-Kerviler, engineer, under the direction of M. de Carcaradec, engineer in chief.

The contractors are MM. Baudet, Donon and C°, whose foundry works are at Argenteuil. The contracts were signed in September 1879, and the three pairs of gates will be put in position in October 1880.

M. Stéphany is the « conducteur » of the works.

XIV

PORT OF HAVRE.

CITADEL BASIN.

I. CONSTRUCTION OF THE CITADEL BASIN.

II. ENLARGEMENT OF THE OUTER PORT, ON THE SOUTH SIDE.

III. COMPLETION OF THE EURE BASIN, AND CONSTRUCTION OF SAINT-JOHN'S DIKE [1].

Bird's eye view of the port and town.

I

CONSTRUCTION OF THE CITADEL BASIN.

This basin comprises two docks, which communicate on one side, with the outer port, by a lock with chamber on the other, with the basin of the Eure by simple lock gates — three dry-docks of graduated dimensions, and two discharge or scouring sluices.

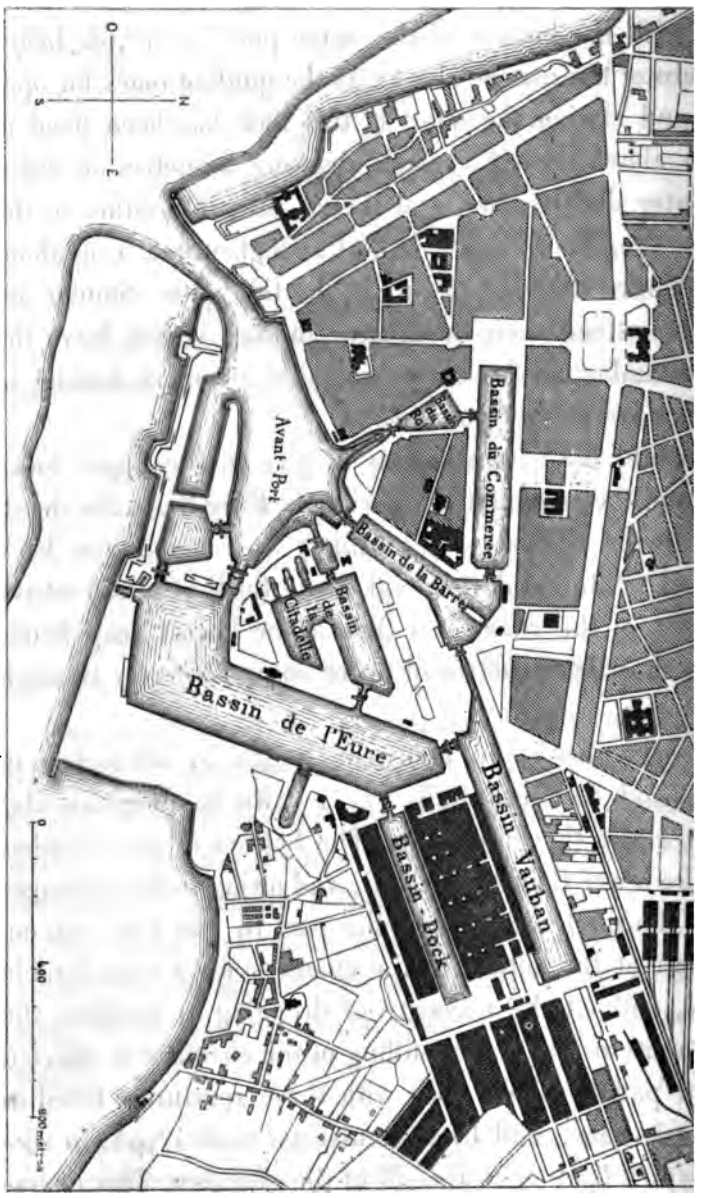
The three navigation locks have a uniform width of 16 metres measured at the crown of the top of the quay walls of the basin. The side walls have an incline of one eighth.

[1] The word «dike» is used to indicate a work in the nature of an embankment, not exclusively a breakwater, and of which the whole, or a great part, is formed by skilled labour of some kind, such as masonry, etc., while an embankment may consist principally of earth piled with regularity. (Translator.

The tail-sill of the lock has been placed on the same level with the bottom of the outer port, or $1^m,65$ below the zero of the marine charts. As the guiding mark for opening and closing the gates of this lock has been fixed at $5^m,30$ above the sill, vessels drawing 5 metres of water can enter the chamber, and thence pass into either of the basins, four hours and a half after high water, i. e. about three hours after the closing of the tide gates. Similar advantages attend their departure; in fact, vessels leave the lock-chamber at the same time that steamers waiting in the port are able to put to sea.

It would have been useless to give to the upper lock-gates and the communication with the Eure Basin the depth given to the tail-gates. Accordingly their height has been reduced $2^m,30$, and their sill made flush at $0^m,65$ above the zero of the charts, so that at the lowest neap flood, vessels drawing 5 metres of water can pass freely through these gates.

The chamber is 80 metres in length by 55 metres in width, and the quay walls are $11^m,30$ in perpendicular height above the foundation. The bottom of the chamber is $0^m,50$ lower than the tail-sill, and owing to this arrangement, the mud carried into the port by the tide, can accumulate at the bottom of the chamber for a considerable period, without the necessity of dredging to facilitate the movements of vessels. The filling of the chamber is effected by four paddle-valves, each with three apertures, fitted in the upper gates, and by two culverts, each $1^m,94$, in section, which lead on to the sill of the chamber. This operation is accomplished in an average time of ten minutes. Two

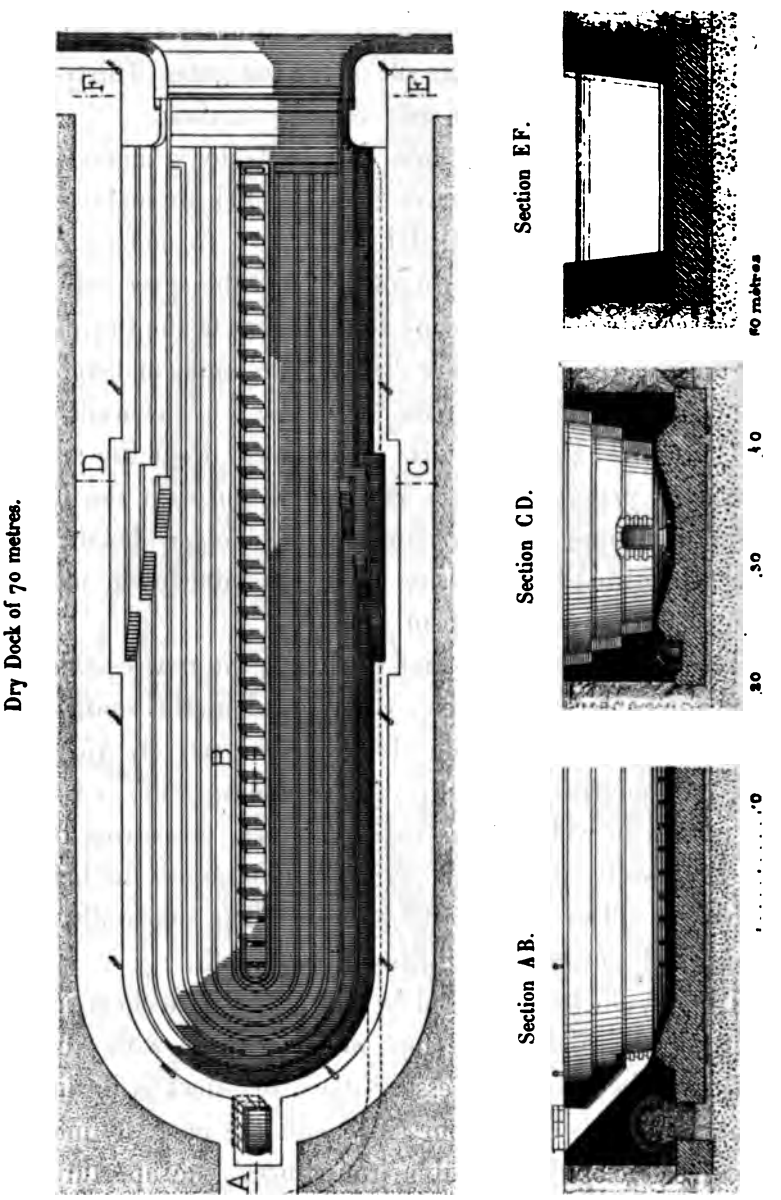

O
S
N
E
Avant-Port
Bassin du Commerce
Bassin de la Barre
Bassin de la Citadelle
Bassin de l'Eure
Bassin Vauban
Bassin-Dock
0
400

other culverts, of the same section as the preceding, serve to empty the chamber, that is to say, to lower the plane of the water $5^{m},30$ above the sill of the tail-gates. Thirty-five minutes are necessary for this second operation.

The basin is divided into two parts by a mole. The northern part, which serves as a channel for manœuvres between the Eure and Citadel Basins, is 110 metres wide; the southern part is only 80 metres, and the space between the extremity of the mole and the entrance to the dry docks is 100 metres. The quay walls have an uniform height of 9 metres above the foundations. The foot of the walls and the bottom of the basin are $0^{m},50$ lower than the sill of the upper gates and of the communication with the Eure Basin, consequently a certain time must elapse before the mud, deposited by the rising tides, can impede the movements of vessels in the basin.

The three dry-docks, that constitute the new establishment for repairs, have been constructed in the south-east bank of the Citadel Basin. They are respectively 45, 55, and 70 metres in length on the blocks; 11, 13 and 16 metres in width at the entrance gates, measuring from the top level; 7 metres, $7^{m},50$ and 8 metres in height above the sill or floor of the entrance. The side walls and banks of these docks are inclined one eighth.

The dry-docks are closed by floating gates in sheet-iron, with a foot-bridge at the top, and are fitted with sluices which fill them when necessary. Each dry-dock is in direct communication, on the one side, with the port, by means of culverts closed by double iron sluices, the aperture of which is at the foot of the sill of the entrance lock; and on


Dry Dock of 70 metres.
F
F
D
C
B
A
Section EF.
Section CD.
Section AB.
40 metres
40
30
20
10

the other side, with a drain-well common to both, to which is attached a steam-pump.

At spring-tides, the three dry-docks are completely drained at low water by means of the culverts which discharge into the outer port. At neap-tides this is not the case, and it is necessary to pump out a channel the depth of which is $1^m,90$ for n° 1 dock, $2^m,40$ for n° 2, and $2^m,90$ for n° 3.

The two scouring sluices are situated side by side, and open into the Citadel Basin between the upper gates and the dry-dock n° 3, and into the outer port near the southern wing-wall of the tail-gates of the lock.

Each lock-gate is $6^m,20$ in breadth by 7 metres in height, and is closed by a turning gate and a pair of sash-gates. The gates open and shut by the simple action of the current, and the object of the sash-gates is to protect them from the swell in the port.

The inverts or floors are horizontal and made flush at $2^m,15$ higher than the zero of the charts, for a length of 28 metres starting from the upper sill; they then incline, following a regular slope, so as to reach at the lower aperture the level of the bottom of the outer port ($1^m,65$ below the zero). The total difference between the upper and lower level is therefore $3^m,80$. Besides the Citadel Basin, the supply reservoir of the discharge sluices includes the Eure Basin, the entrepôt dock and the Vauban Basin, forming collectively a superficies of 39 hectares. From this calculation it follows that, by lowering the water of the basins only one metre, which at spring-tides would in no wise inconvenience navigation, the scouring sluices could throw a volume

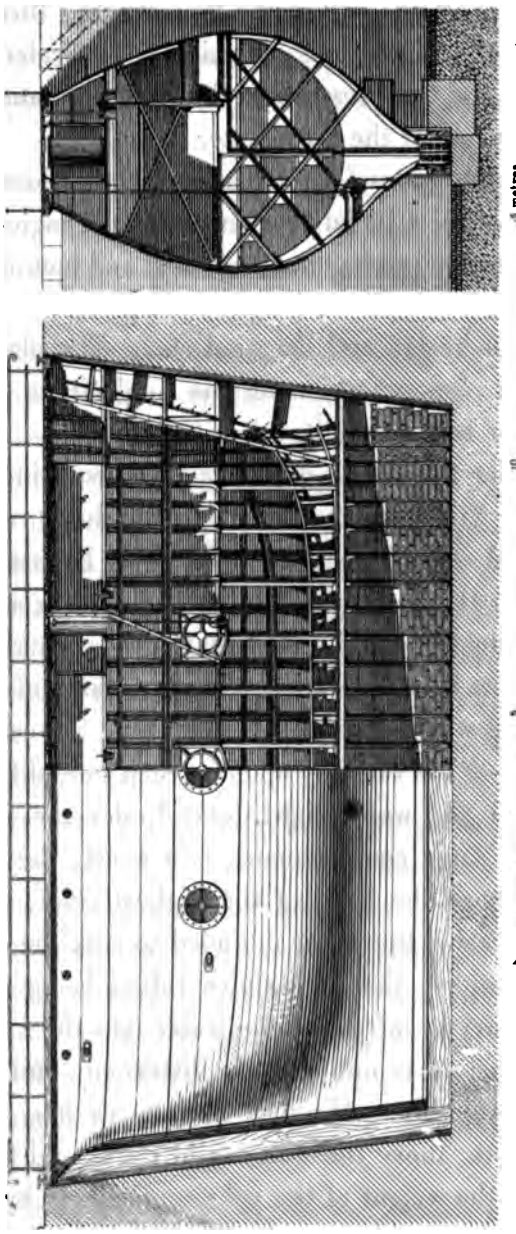
of 390 000 cubic metres of water into the outer port, a ebb-tide.

The tail-gate of the lock and the gate of communicatio with the Eure Basin, are each crossed by an iron swing bridge with a single flap and two ways for vehicles. Eac bridge is $35^{m},17$ in length, $6^{m},94$ in width and consists o two head girders, forming the side-rails, increasing in heigh from the extremities to the point of greatest tension. Thes girders are connected transversely by joists, strengthene by gussets and cross-braces, to which is bolted the crosse wooden flooring that supports the double way for vehicles the two foot-ways, and the ridge separating the two road ways.

The gates of the two locks are of framed timber; the have double leaves and are formed of an oaken frame, th uprights of which are connected by cross-pieces in pine. rigid pine planking is laid over the cross-pieces. Beside th tenons of the frame, the connection of the various parts c the work is secured by means of rows of bands and a doubl corner-band in wrought iron.

The upper gates are $7^{m},40$ in height. The lower gates which are $0^{m},50$ lower in level than the upper gates, ar $9^{m},25$ in height. In order to protect them from the attack of the teredo worm, all the wood-work has three coats o metallic paint, and is covered with nails to a level corresponding with high water at neap-tide.

The swing gates and discharge sluices are also in framed timber. Each of these gates is formed of a single leaf, $5^{m},7$ in height, by $6^{m},16$ in breadth, divided into two unequa parts by the vertical axis on which it moves. The difference



Floating gate of the Dry Dock of 70 metres.

in breadth is $0^{m},06$, and in the largest side a turning sluice is placed, the dimensions of which are so calculated that when it opens, the pressure of the water preponderates on the smaller leaf of the large gate.

The floating gates (*bateaux-portes*) which close the three dry-docks of the Citadel, are in plate and angle-iron. The frame pieces are put together on a keel and bound by strong floor timbers, a keelson, longitudinal pieces, a water-tight deck, a foot-bridge and diagonal stays. The plates of iron are riveted clinker fashion on the angle-irons, and make the chest or hull perfectly water-tight.

The water-tight deck divides each caisson into two distinct parts. The lower part forming the float, contains the ballast, and should be always dry. This ballast is so regulated, that the caisson left to itself, floats on a level with the water-tight deck. The other part can either remain dry, or be put in communication with the water of the basin. With this view, two or three sluice-valves, according to the dimensions of the caisson, open in each side of the hull on a level with the water-tight deck. Under the foot-bridge and in the same compartment, is a chest, the bottom of which is above the level of the highest tides, and which serves to receive the water intended to sink the caisson.

To accomplish this, the sluice-valves being open, it is only necessary to introduce the water into the upper chest. The equilibrium is immediately disturbed, and the water from the basin flows through the sluices into the upper compartment, above the water-tight deck, and the caisson sinks until the weight of the volume displaced by the plate and the angle-irons, is equal to the weight of the water in-

troduced into the chest. And as under the most unfavourable circumstances the volume displaced is of little importance, a small quantity of water is sufficient to sink the caisson.

The cost of all these works, including the reconstruction of the eastern quay wall of the port and the expenses of survey and superintendence amounted to 10 100 854 fr. 04 cent.

These works were executed from 1865 to 1871, and directed by M. Hérard, engineer in chief, and M. Bellot, engineer « des Ponts et Chaussées ».

The public utility of the following works was declared by a decree of the 18th July 1870. The enlargement of the outer port on the south side; the completion of the Eure and Vauban basins; the construction of Saint-John's Dike, and some other works of minor importance. The outlay was estimated at 14 millions, half of which was to be borne by the State, and half by the Chamber of Commerce. (Act of the 22nd July 1870.)

The allocations of the budget did not permit the State to furnish the capital agreed upon, within the appointed time, and the Chamber of Commerce therefore proposed to advance 6 millions; this offer was accepted and confirmed by an act passed on the 5th August 1874. The repayment of this advance with interest at 4 1/2 per cent, was commenced in 1875, and will be effected in fifteen annuities, for the payment of which a sum will be allotted in the budget.

For the capital advanced, as also for the loss of interest, the Chamber of Commerce will be reimbursed by the pro-

ceeds of a toll levied on vessels, the rate of which was fixed at $0^{f},75$, without decime per ton measurement, for French, and $0^{f},90$ for foreign vessels. A reduction of $0^{f},30$ is made in the case of vessels laden with coal, pine timber, or ice, on the whole or in the proportion of more than nine tenths. French coasting vessels are exempted from these dues, as also are all foreign vessels putting in shelter, water, or supplies, and leaving the port without effecting any commercial operation; also vessels entering and leaving in ballast.

The following table shows the financial situation of the different works:

DESCRIPTION OF WORKS.	AMOUNT		
	AUTHORIZED by decree of the 18th July 1870.	APPROPRIATED (amount for plans approved).	FINISHED up 31st December 1879.
Enlargement of the outer port on the south side.....	7 500 000^{f}	7 181 581^{f},63	6 651 337^{f},39
Construction of the great Florida lock-chamber.....	1 150 000	"	"
Completion of the Eure basin and formation of the Saint-John's dike.....	3 250 000	5 016 062 ,03	5 016 062 ,03
Completion of the Vauban basin.	1 000 000	144 277 ,14	121 521 ,03
Contingent expenses; sundry works.....	1 100 000	1 407 707 ,42	1 352 707 ,42
TOTALS.....	14 000 000	13 749 628 ,22	13 141 627 ,87

II

ENLARGEMENT OF THE OUTER PORT ON THE SOUTH SIDE.

Object of the works. — The enlargement of the outer port was undertaken with the view of facilitating the move-

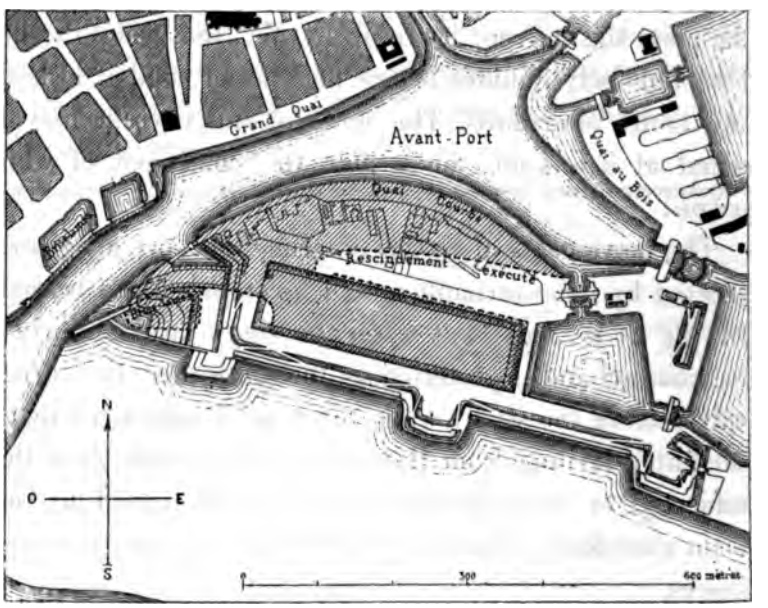
ments of large ships, and of forming outside of the lines of access a port for steam-tugs and vessels putting in for shelter or supplies. When the tide is rising, the current of the flood runs straight to the piers of the port, and preserves this direction until the embouchure of the Seine is full; but at that moment a counter-current called « verhaule » commences in the north part of the bay. At the opening of the piers this current bears 65° N. W.; its strength is first observed forty minutes before high water, and it lasts for two hours afterwards. The force of this current may be stated at 2,5 knots for a tide the coefficient of which is 100.

The movements of vessels entering the port are greatly affected by the « verhaule », which compels them to make for the S. W. side, but when the ship's head is fairly in the channel and is protected by the south pier, the current only acts on the stern, while the head is influenced by the current returning from the north pier. Vessels were thus subjected to two opposing forces, which tended to turn them completely round, and drive them on the discharge sluices.

When this danger was avoided, and the vessels were nearly parallel to the piers, they were obliged to return to the S. E. in order to reach the gates of the Transatlantic basin. It was necessary for them to make an arc of a circle of 400 metres radius, and this manœuvre was the more difficult, as slow sailing vessels, drawing but little water, do not always answer the helm in a satisfactory manner, and they were besides liable to be driven to the north by the reflux of the water between them and the Courbe Quay.

And it sometimes happened that large steamers were stranded on the talus in front of the great quay.

The widening of the outer port has removed these difficulties and vessels can make an arc of a circle of more than 900 metres radius. Additional mooring stations are also provided for vessels touching at the port, and for the tugs,



the number of which is sometimes considerable, and by these means no obstruction is offered to the movements of vessels entering the basins.

General dispositions. — The Courbe Quay has been demolished, and the Florida Quay divided into two parts by a traverse; the western or larger division has been joined to the outer port, and a channel of 80 metres affords

access to this new outer port which is separated from the old one by a stone mole.

A large breakwater has been constructed opposite the north pier, and a flight of steps gives access to the south beach.

In the original plan, it was intended to place the south pier in the rear of the position it actually occupies. New plans were made with the view of replacing it by an open timber jetty, which would allow the rising tide to pass through it and thus diminish the force of the current.

The breadth of the old outer port was increased from 90 to 185 metres in the central part, and the annex is 290 metres long by 100 metres broad. The intermediate mole is 345 metres in length and has a breadth varying from 26 to 65 metres. It terminates in a stone wing-wall.

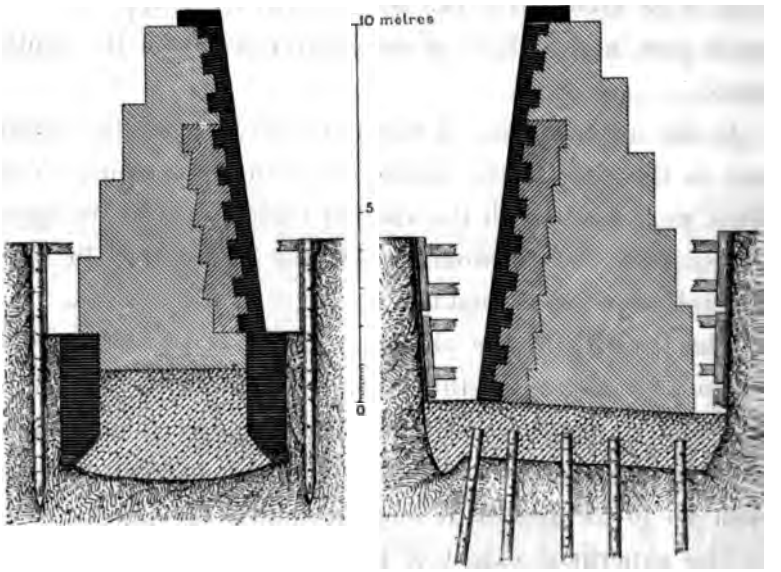
The superficial extent of the outer port has been augmented from 11 hectares 21 ares to 21 hectares 34 ares. The extension of the quays available for traffic attains to 1790 metres and the superficial extent of the earthworks to 30 600 square metres.

Description of the works. — In the following description, the figures given for the levels are taken as commencing from the zero of the marine charts.

The walls of the mole and the eastern wall of the annex are founded on rows of piles, from 4 to 9 metres long and $0^{m},30$ in diameter. The walls are $10^{m},50$ in height, not including the foundation layer of beton $1^{m},50$ thick; the wing-wall of the mole has been raised 1 metre.

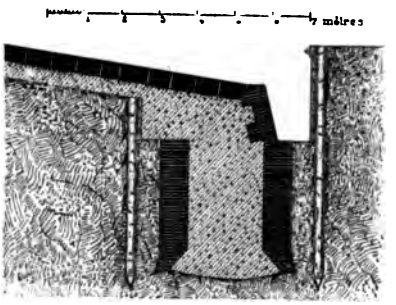
The south wall of the annex is founded on blocks of

masonry, which were sunk to the solid bottom to at least — 2m,85. This foundation being obtained and levelled to a



South wall. Mole wall.

figure varying from 0m,65 to 0m,15, the upper part of the quay wall was built upon it according to the perpendicular section.



Sill of the breakwater.

Generally speaking, the quays rise to 9m,15 and the sill of the breakwater to 2m,15. The bottom presents an uneven surface with a slope varying from 0m,08 to 0m,27 per metre. The interior of the breakwater has an average breadth of 51 metres.

A flight of steps, giving access to the south shingle, has

been formed alongside the moat of the fortifications; a paved road passes round the breakwater and enables vehicles to reach the wing-wall of the pier. These two ways were constructed on arches to obviate the possibility of settlement.

The quay walls are built with a batter of 1/7; the facings visible, are in brickwork $0^m,56$ in thickness, while the filling in is of rubble. The quay walls and piers are crowned by a granite course of $0^m,35$. The bottom of the breakwater is formed of rock ashlar $0^m,50$ in average thickness, set on a layer of beton $0^m,30$.

The stockade or framing of the breakwater is 105 metres long, and, with the exception of the top or platform, is made entirely of iron. It consists of uprights 6 metres apart from centre to centre, with intermediate posts $1^m,20$ from each other.

The superficial extent joined to the old outer port is hollowed to $2^m,35$, while the annex is only cleared to $0^m,15$.

The entire mass of excavated rubbish amounts to 975 000 cubic metres, 294 000 of which were dredged; the measurement of the demolitions reaches to 85 950 cubic metres, of which 66 060 were taken away at ebb tide. The number of piles is 3 975, and the cube of the temporary framework for shoring and discharge drains is about 3 355 metres. The masonry and brickwork of all description represent a mass of 84 900 cubic metres, 25 500 of which were executed at low water.

Method of executing the work. — For the general work of clearing and excavating, the coffer-dams afforded

sufficient protection, as also for the walls of the quay, th mole, the annex, and the eastern abutment of the break water. For this purpose, the work was commenced b constructing the earth-work traverse, which divides th Florida Basin into two parts, and by walling up the discharg sluices with stone.

The complement of the breakwater, some earthworks the demolition of the Courbe Quay, of the Florida discharg sluices, and the Harcourt and Vidame breakwaters, wer executed as the tides permitted.

The excavation of the superficies annexed to the oute port was effected by dredging.

The bottom was completely drained by means of power ful pumping machinery, and the excavations were conse quently made under favourable conditions. The upper par consisted of the shingle and sand of the old beach, and be low this formation, sand more or less argillaceous, an traversed by beds of peat. The argillaceous sand varies i thickness, and rests on a layer of shingle, which is found a different depths under the whole extent of the town o Havre. On the site of the works, the depth of this laye varied from $-2^{m},40$ to $-14^{m},10$. In some parts of th south side, the argillaceous sand ceased to appear, and i its place was found a bed of moving sand of a watery con sistence, and from $1^{m},10$ to $2^{m},80$ in thickness.

The foundations of the mole walls and the east wall of th annex were laid by the aid of plank-piling. When the earth works in general attained $3^{m},15$, it was consequently ne cessary to make a cutting or trench on the site of the wall the sides of this cutting were nearly vertical, and were sup

ported by means of a revetment of heavy planking, with timber framing of horizontal stays and vertical uprights. As soon as an average of $-3^{m},10$ was reached, the piles were driven home and the wall constructed. The wood employed for supporting the sides of the excavation was removed as the masonry advanced; the cube of this timber was about $2^{m},85$ per metre run.

The foundations of the works by the side of the fortifications and the south pier, could not be laid in the same manner, on account of the moving sands, and recourse was had to shafts in masonry.

When the excavation attained $3^{m},15$, two rows of piles were driven in, the one, in front of the site of the wall, the other, behind it. The piles were $1^{m},50$ apart in each row, and strong planking was nailed to them in order to support the sides of the excavation, which was stopped a little above the level of the shifting sands, and frames of timber, varying in dimensions but of uniform structure, were laid on the bottom. These frames were formed of three courses of strong timbers, one above another, cut on the bevel; they were $0^{m},24$ in height, $0^{m},30$ at the lower part, and $0^{m},60$ at the upper. This framing was crowned by brickwork each course of bricks projecting $0^{m},05$ on the preceding course, until the shaft attained its normal thickness.

When the mortar had sufficiently set, the workmen cleared out the interior of the frame, the pumps worked at the same time and the bottom of the excavation being reached the brickwork was commenced. This operation was repeated until the bottom of the frame attained the depth required; the shaft was then filled in with beton.

The space between the quay walls and the frames, was also filled in with beton for about $0^m,80$, in order to hold back the sand. To accomplish this, panels were sunk in front and rear, and the space between these and the frames was cleared of sand. In some parts, the sand was in such a fluid state that it was necessary to calk the joints of the panels.

The general size of the frames was 6 metres by 6; those of the east abutment were 6 metres by 8, while those of the sill were only $3^m,70$ by $5^m,70$. The breadth of the crown was usually $1^m,03$, but this was increased to $1^m,14$ for the frames of the east abutment of the breakwater, and reduced to $0^m,80$ for those of the sill.

In the curved part of the pier, the form of the frames was altered; the two lateral faces were placed so as to follow the radii of the curve, and the front consisted of two straight parts forming a very open angle.

The crossing of the fortifications presented difficulties of a special nature. The new quay wall was situated partly on the site of the south abutment of the discharge channels, its construction was therefore obliged to be effected at two different times, and under very precarious conditions.

The back part of the wall was built first, in an excavation protected by plank piling, commencing from $7^m,75$ and founded on frames at a depth of $0^m,65$. The shafts were sunk to $2^m,85$, or $3^m,90$ below the foundations of the discharge channels, and $25^m,65$ below the top of the Florida embankment. The discharge channels were afterwards demolished and the front part of the pier built on frames. But in consequence of the narrowness of the space at disposal, the

hafts were only bricked on three sides, and the fourth was ormed by three wooden beams. A sheet-pile prevented the and from entering the frame and the back of the wall aleady built. Owing to these precautions, the stability of the vall was assured, and no movement has been observed.

To sink a frame of $3^{m},50$, the clearing out of the interior was carried on for a period of time varying from 35 to 30 hours, and which averaged 50 hours. The sinking was herefore effected at a rate of about $0^{m},07$ an hour of actual work. An average of 1 hour 44 minutes was required or a workman to dig out a cubic metre, and load it into a ub, which was hoisted by a steam crane. From 11 to 16 hours were required to sink the intermediate frames.

The mass of stuff excavated exceeded by 24 or 25 per cent the cube of the materials employed for the construction and the filling in of the frames and intermediate frames. This difference arose from the abundance of the stuff excavated, and of that which fell in laterally. At the sill of the break-water, which was executed at ebb-tide, the excavations represented nearly double the cube of the materials used in the construction; this difference was caused by the deposits of the tide which flowed over the work twice a day and brought with it into the frames large quantities of sand and shingle.

Portland cement was used for the following works; for the beton-work, the brickwork, the filling in, which was done at low water below $6^{m},15$; and also the filling in done in the dry, below the above mentioned figure; and on an average thickness of $0^{m},94$ the brick facing. The mortar was made of 400 kilogrammes of cement to 1 cubic metre

of sand. An exception was made with regard to the frames constructed at low water, and the lower part of those made in the dry, and for about $1^{m},50$ the mortar contained more cement and was mixed in the proportions of 800 kilogrammes of cement to 1 cubic metre of sand; all the other work was done with hydraulic lime from La Hêve.

The water was admitted into the works on tke 8th October 1876, up to which date the pumping was effected by three sets of machinery each comprising two movable engines and two pumps. The construction of a part of the mole walls necessitated the employment of an additional engine with one pump, and in addition a movable engine and pump were required expressly for the frames. The engines were nominally of 18 horse-power but could be worked up to more than 30.

Ordinarily, four movable engines and four pumps were constantly working, and could only be stopped for about half an hour at low water. The other engines were available in case of accident, but it was sometimes necessary to employ them when additional power was required, as in the case of high spring tides.

The height to which the water was raised by the pumps, was reduced from as much as possible, and varied from 5 metres to $13^{m},10$, but for the most part it reached to from 8 to 10 metres.

The movable engines had their steam up 94 948 hours, and the pumps worked 89 718 hours. The volume of water raised from the excavations was not less than 16 or 17 cubic metres a minute or from 23 to 24 500 cubic metres a day.

The constructions and demolitions undertaken since October 1876, were effected by means of coffer-dams, levelled to between 2 and 3 metres; at flood tide, these were completely submerged; behind these coffer-dams, pumping was carried on energetically, as soon as the level of the water was lower than the top of the dam. Ten movable engines and ten rotary pumps were employed at the works.

The contracts for the earthworks and masonry were finished on the 1st March 1880; a few works executed under inspection remain to be finished, especially the lower part of the steps giving access to the south shingle beach.

The iron stockade was commenced in the course of the mounth of March, and presented no special difficulty. The various pieces of which it consists were brought to the causeway of the breakwater, the girders were put together, and at low tide were got as far as the sill of the breakwater. They were then raised by a winch placed on the parts already in position; at the commencement of the work this winch was established on the west abutment. As soon as the girders or uprights are raised, they are joined at the top by beams which constitute the platform, and on which is fixed the oaken flooring.

The work consists of 171 500 kilogrammes of cast and sheet-iron, galvanized to prevent oxidation.

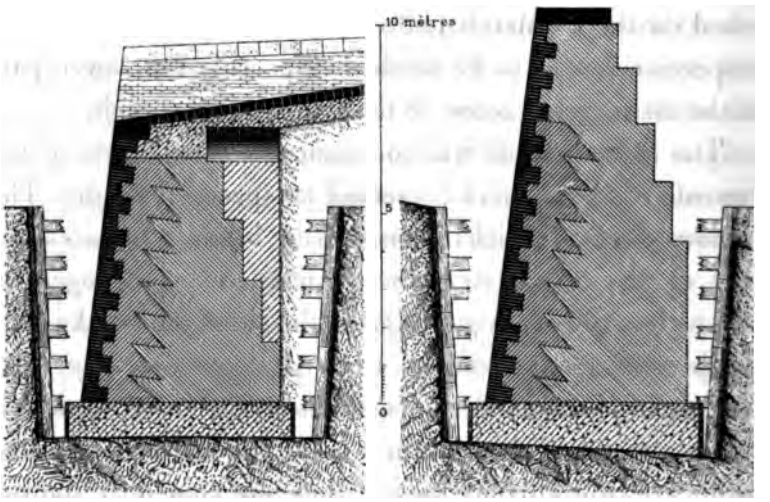
The plans were drawn and the works executed, under the direction of M. Hérard (previously to the 1st October 1876) and Bellot (after the 1st October 1876) engineers in chief, by M. Quinette de Rochemont, engineer, assisted by MM. Delorme, Decolliveaux and Glaneux, « conducteurs ».

III

COMPLETION OF THE EURE BASIN

AND CONSTRUCTION OF SAINT-JOHN'S DIKE.

Description of the work. — The completion of th Eure basin comprised; the construction of the East and Sout quays for a length of 647 metres, the removal of the coffe



Timber Slip. Quay Wall.

dams by means of which the walls were built, and the dee pening of the basin.

The length of the East quay is 457 metres, and of th South, 190 metres. Both are levelled to $9^{m},15$, and ar founded on a layer of beton 1 metre in thickness, restin on the bottom at $-2^{m},35$ for the East wall and $-1^{m},3$ for the south wall. The flagging which forms the crown, i $0^{m},35$ thick and 2 metres broad.

A slip 100 metres long, for timber, was placed at th

South part of the basin; the quay wall in this place stops at $7^{m},15$.

The inclined plane behind is $20^{m},42$ broad with a slope of about $0^{m},13$ per metre; it is faced with stone paving on a beton foundation $0^{m},60$ in thickness.

An entrance lock, for a dry-dock, has been formed at the northern end of the east wall, and its completion is decided upon.

This lock is 10 metres long at the crown, and $11^{m},38$ at the level of the floor. It consits of two parts; the first is $5^{m},50$ in length at the crown and $6^{m},88$ at the low level, and affords space for the working of the floating gate; the second $4^{m},50$ long, corresponds to the upper-sill. Behind the lock, the chamber-walls of the dock are commenced for a certain length ($5^{m},50$ at the low level and $2^{m},75$ at the crown.

The lock is 20 metres broad at the crown in the part corresponding to the upper sill and 21 metres in the floating gate end. The upper sill is $-1^{m},35$, and the lower $-1^{m},85$.

The beton of the foundation rests upon a bottom of sand; it is a sunk to a depth of $-4^{m},85$. The floor is in beton throughout, and faced with brickwork $0^{m},22$ in thickness, the sill is of granite.

Circular aqueducts, $1^{m},30$ in diameter, were formed in the walls, for the purpose of filling the dock; they discharge into the Eure basin at a depth of $1^{m},75$.

The Eure basin was excavated to a depth of $-1^{m},10$ at the north of the dock gates, $-1^{m},35$ between the dock gates and the dry-dock, and $1^{m},65$ at the south of the dry-dock,

except at the foot of the walls of the East and South quays In front of the East wall, is a platform 55 metres broad a a depth of — $1^{m},35$, and in front of the South quay a plat form 30 metres broad at $0^{m},35$. This latter joins the bot tom of the basin at — $1^{m},65$ by means of steps 5 metre broad and $0^{m},20$ high.

The total mass of excavated stuff was 649 779 cubic me tres, of which 506 469 were dredged in order to remov the coffer-dams and deepen the basin. The masonry attaine to 40 843 cubic metres, and the temporary woodwork fo stays and pumping troughs to 5 885 metres.

The Eure Basin, partly reclaimed from the sea, wa formerly protected on the south side by a simple stockad or barrier of timber; the defective condition of this wor led to its demolition and replacement. The new dike c Saint-John was constructed of stone; it commences at th left face of the last bastion of the Florida, and is carried t the Neiges point in a straight line 550 metres long.

The foundation is laid at depth of $2^{m},15$ on a layer c beton, the thickness of which varies from 1 to 2 metre The section of the facing is curved, and describes an arc c a circle with a radius of $10^{m},875$. The facing in rear is ver tical. The masonry is flushed to $10^{m},15$, and is crowned b a granite flagging $0^{m},50$ in height and $1^{m},20$ in breadth behind which is a scappled paving $1^{m},90$ in breadth set i a bed of mortar. A granite coping, $0^{m},70$ in height an $0^{m},80$ in breadth, crowns the flagging.

The facing in brickwork is $0^{m},66$ in average thickness i front, and $0^{m},45$ in the rear of the dike.

The space between the old stockade and the new wa

was filled up with the rubbish from the works in the outer port.

The mass of masonry and brickwork of all descriptions measures 19391 cubic metres, of which, 8309 were executed at low water.

Method of executing the work. — The quays of the Eure Basin and the lock of the dry-dock were built by means of cofferdams formed by the old banks of the basin; and with this view, the talus limiting the plane of water were disposed in front of the site of the walls.

The foundations of the quays were laid by means of plank-piling at $4^{m},15$. The lock of the dry-dock was constructed on two different times; the first part built also by means of plank-piling was that which corresponds, to the quay wall of the basin; afterwards the rear part of the work was completed. A stone wall was built in the lock for the purpose of serving as a cofferdam during the construction of the dry-dock; in the mean time it can be utilized as a quay wall.

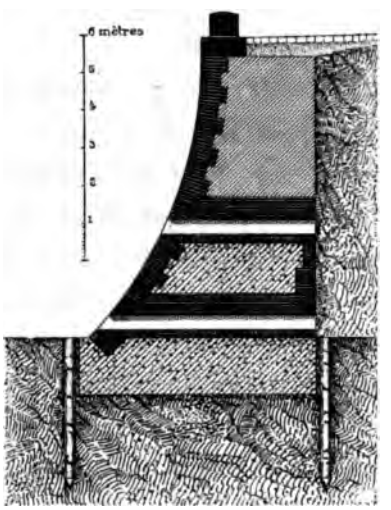
The method of carrying out the work, and the nature of the materials employed, are the same as those adopted for the enlargement of the outer port, the only difference made was in mixing the mortar for the foundation beton, the proposition of cement being increased to 500 kilogrammes per cubic metres of sand.

The pumping for building the walls was effected by two movable engines and two pumps; the pipes were laid along the frames of the plank piling and led down to the drain-wells, which were situated at a maximum distance of

100 metres from the pumps. The volume of water raised was, on the average, 6 metres a minute. Three steam-engines of from 25 to 30 horse-power each, worked a Letestu pump and two centrifugal pumps, and were employe for the foundation of the begining of the dry-dock.

The water was pumped from a drain-well sunk to $-6^{m},8$ and raised to $7^{m},15$. The volume raised was from 6 to 1 cubic metres per minute.

The construction of Saint-John's Dike was commenced b driving two lines of pile into the beach $7^{m},10$ distant from centre to centre and 5 metres in length by $0^{m},30$ in average diameter; in the rows they were $1^{m},50$ apart; the excavations were then carried o and the ground supporte on both sides by plankin $0^{m},06$ thick, nailed to th piles.



Saint John's Dike.

The excavation havin reached the depth of $0^{m},6$ along 360 metres to the west and $0^{m},15$ along the rest of th length, it was filled in with beton to $2^{m},15$; above this foun dation the stonework commenced and was carried up t $5^{m},93$. With the exception of the two facings, the whol dike is in beton; the solid mass is traversed by three row of barbacanes or drains $0^{m},11$ in breadth by $0^{m},35$ i height; in each row the barbacanes are 10 metres apart fro

centre to centre and are in brickwork $0^{m},22$ thick. Above $5^{m},93$ the filling in behind the visible facings, is entirely of rubble.

A dry wall or stone packing was built up againt the dike; it begins at a depth of $2^{m},15$, and is carried up to $5^{m},51$; the breadth at the base is $2^{m},50$ and at the upper 1 metre. It is built to facilitate the drainage of the earthworks executed at low water, behind the dike.

The masonry and brickwork were all executed with Portland cement, in the proportion of 500 kilogrammes of cement to 1 cubic metre of sand for the foundation beton above $2^{m},15$, and 400 kilogrammes of cement to 1 cubic metre of sand for all the other work.

Steam-engines were stationed on the old stockade of Saint-John, and worked the pumps at the foot of the stockade; the water was led to the pumps by a horizontal conduit placed on the ground; the maximum length of this conduit was 250 metres. Two of these engines were generally working. They were from 16 to 18 horse-power and raised a volume of water equal to 10 cubic metres a minute.

The engineers who designed the plans and directed the works, were M. Hérard, engineer in chief; M. Bellot, belonging to the service first as engineer, then as engineer in chief; and MM. Quinette de Rochemont and Renaud, engineers. Among the « conducteurs », MM. Goëls, Renout, Gérard and Glaneur should be mentioned.

FIFTH SECTION.

LIGHTHOUSES AND BEACONS.

XV

THE TRIAGOZ LIGHTHOUSE.

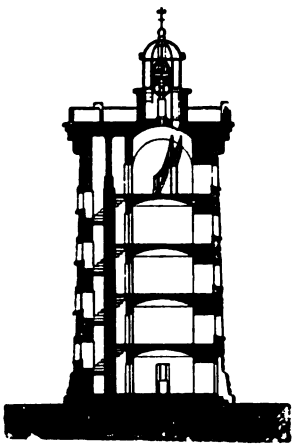
(DEPARTMENT OF THE CÔTES-DU-NORD.)

General view of the lighthouse.

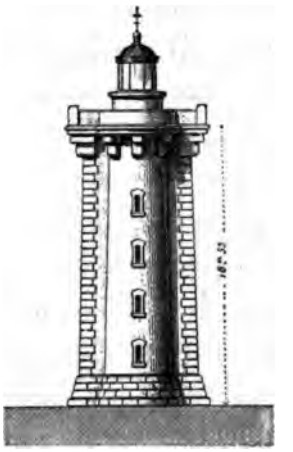
The Triagoz lighthouse indicates to mariners the positic of the rock so called which is situated east of the Sept-Ile in the Channel.

This lighthouse is of the Third Order and is erected up an isolated rock the base of which rises to a height of 8 m tres above the level of the higest tides; its construction co sequently allowed arrangements to be adopted differi from those of lighthouses of which the base is submerge The three figures accompanying this notice give the pla the transversal course and the posterior elevation of t building.

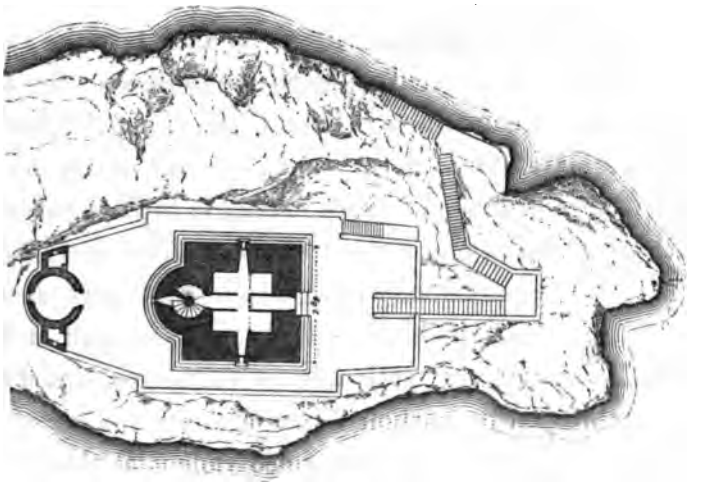
It consists of a square tower, with a staircase projecti from one of its sides. On the ground level is an entran leading the staircase, with a storeroom on each side. Abo



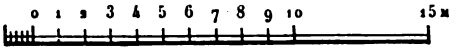
Transversal section.



Posterior elevation.



Plan.



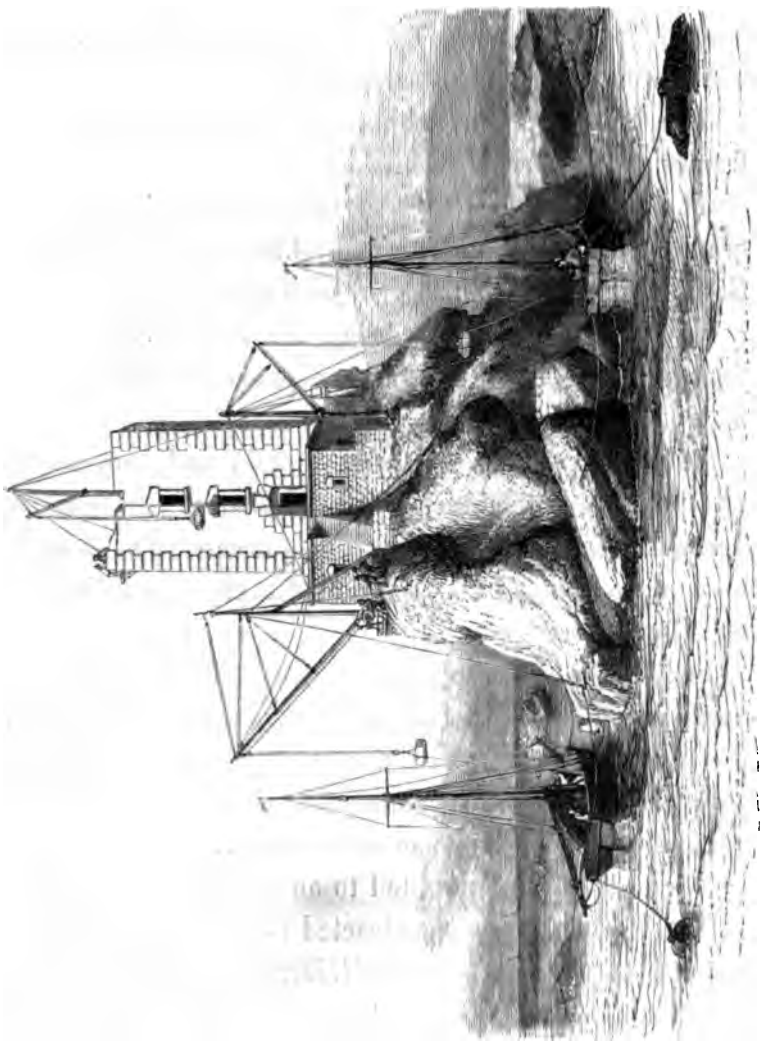
the ground floor are three rooms, one of which is reserve for the engineers; they are cross-vaulted and fitted wit chimneys. At the top of the tower is the service room fro which a cast-iron staircase leads up to the lantern; thi room is also used for the storage of such articles as woul suffer deterioration from exposure to damp.

A platform, following the rock in shape, surrounds th edifice; it is accessible by stairs placed on that side of th rock which offers the greatest facilities for landing. Unde the fore part are magazines for wood and various necessarie and at the end is a small reduct, which adds to the storag accommodation of the lighthouse.

The plateau of Triagoz is of considerable extent, bein nearly four miles long from east to west and one mile broa but only a few isolated rocks are seen above the water, eve at the lowest tides. The rock chosen for the site of the ligh house is the most elevated point on the southern side, an on the north it consequently bounds the channel followe in coasting navigation. At the south, the side of the rock almost perpendicular and in descending to the opposite sid it extends in such a manner as to form a small creek ope at the east; it is more easy of access in that part durin three or four hours of ebb-tide. The depth of water, at th foot of the rock on the south side, is 20 metres, and it i creases rapidly in proportion to the distance; the bottom of rock and the tidal currents are so violent at this poin that is was necessary to abandon the idea of anchoring small vessel there for the accommodation of the workm during the fine weather, as had been previously intended.

A hut or cabin was built on the site of the tower, as so

as the top of the rock was levelled. An upright mast with a jib, was set up in the centre of the construction and served



to raise the stones. The landing of the materials was effected by means of derricks of similar form, fixed in the

rock, one at the northern entrance of the little creek, th other on the south-east point of the rock. It was carried o energetically whenever the state of the sea permitted th craft to come alongside. The drawing opposite gives a vie of the works during their execution.

The building is in rubble, with chain-courses, socles frames and cornice in granite ashlar.

The rubble facings between the ashlar angles are in re granite from Ploumanac'h. The ashlar came from the Ile Grande and is of a bluish grey with a fine grain.

This contrast of colours brings out in forcible relief th lines of a building of which few persons are called upon t make a close inspection.

The works were commenced in 1861 and completed i 1864. Serious difficulties presented themselves, especiall during the first season, when it was necessary to bring th working apparatus back to the land every day, a distance o 21 kilometres.

Such is the violence of the waves, that since the light house was finished, the waves have frequently washed ove the lower platform, and the spray has reached the uppe one. Nevertheless no accident took place during the con struction, and no workman was injuried.

The total outlay amounted to about 300 000 francs.

The works were not contracted for, but executed unde inspection, and directed by MM. Dujardin, engineer in chie and Pelaud, engineer who prepared the plan, and under th assiduous superintendence of MM. Abgrall, « conducteur and Perron, at the head of the working arrangements.

XVI

LA CROIX LIGHTHOUSE.

(DEPARTMENT OF THE CÔTES-DU-NORD.)

General view of the lighthouse.

The great entrance passage of Trieux (Côtes-du-Nord) is indicated by two lights; one of which is established on the heights of Bodic, to the left of the embouchure, the other is on an isolated rock which is 2000 metres from the shore, and is called La Croix. The luminous range of both lighthouses is only required to pervade an angular and limited space, so that the lighting apparatus consists of parabolic reflectors fixed in the upper chambers, in front of the windows opening in the direction of the passage. The lights are twinkling, and cannot be confounded with any other lights on the neighbouring coasts.

The top of the La Croix rock scarcely emerges from the level of the highest equinoctial tides. All the sides of the rock are nearly perpendicular, but between them is an irregular plateau, within the boundaries of which it was just possible to describe the circular base of the tower. This is divided into four stories surmounted by a platform, constituting the sole promenade at the disposal of the keepers. The ground floor serves as vestibule and storeroom, the first story as a kitchen, the second as keeper's bedroom while

the third includes the service room and lighting apparatus.

It was necessary to fix the stairs in a small engaged tower founded 5 metres below the plateau on which the large to er rests.

In order to leave the most elevated part of the edifice in the centre indicated by the light, the stairs do not reach beyond the third stage, and access to the upper platform can only be gained by a movable ladder from the chamber of service.

The building is constructed entirely of granite ashlar from the Ile-Grande. The materials were prepared in a work-yard established in the little port of Loguivy, east of the entrance of Trieux. A railway brought them to a special place of embarkation where they were loaded into lighters, which took them to the very foot of La Croix. This transport did not present any difficulty, for the sea is seldom dangerous in these parts, but the currents are so violent that the passage backwards and forwards could only be accomplished at certain hours of the tide. The workmen employed in the construction could not be subjected to these conditions, and they were therefore installed in a small vessel, anchored permanently near the rock. Once only, this vessel broke from her moorings, and was obliged to seek shelter in the port of Loguivy.

The system of hoisting the materials is one of great simplicity, and has already been employed in several similar undertakings.

A loading derrick with an oblique jib, was established on a projection of the rock in that part of the channel where the lighters come alongside. It lifted the materials, and by a rotary movement, deposited them on some points of rock

levelled as a platform. Another similar derrick was placed i the interior of the lighthouse tower, and secured by mean of a frame, which was raised successively on the springer of each story, in proportion to the progress of the vault.

This derrick was placed, not in the centre of the prin cipal tower, but nearer the centre of the stair tower. In thi manner the materials collected on the platform of depos could be carried by the rotation of the jib to one tower o the other, very near the position required. Besides, thi arrangement, by leaving the central part of the tower clear allowed room for an apparatus of verification, formed of radius movable round the centre, and which was marke from top to bottom of the construction by a plumb line.

The stonework was commenced in May 1865, and fin ished at the end of 1866. The only stoppage experience was in consequence of the tempests of the latter year, whic for long intervals completely prevented the arrival of supplie of dressed stone.

Excepting the supply and preparation of materials, th work were not contracted for but entirely executed unde the direction of MM. Dujardin, engineer in chief, de la Tri bonnière, engineer, and under the assiduous managemen of M. Beaugrand, « conducteur ».

XVII

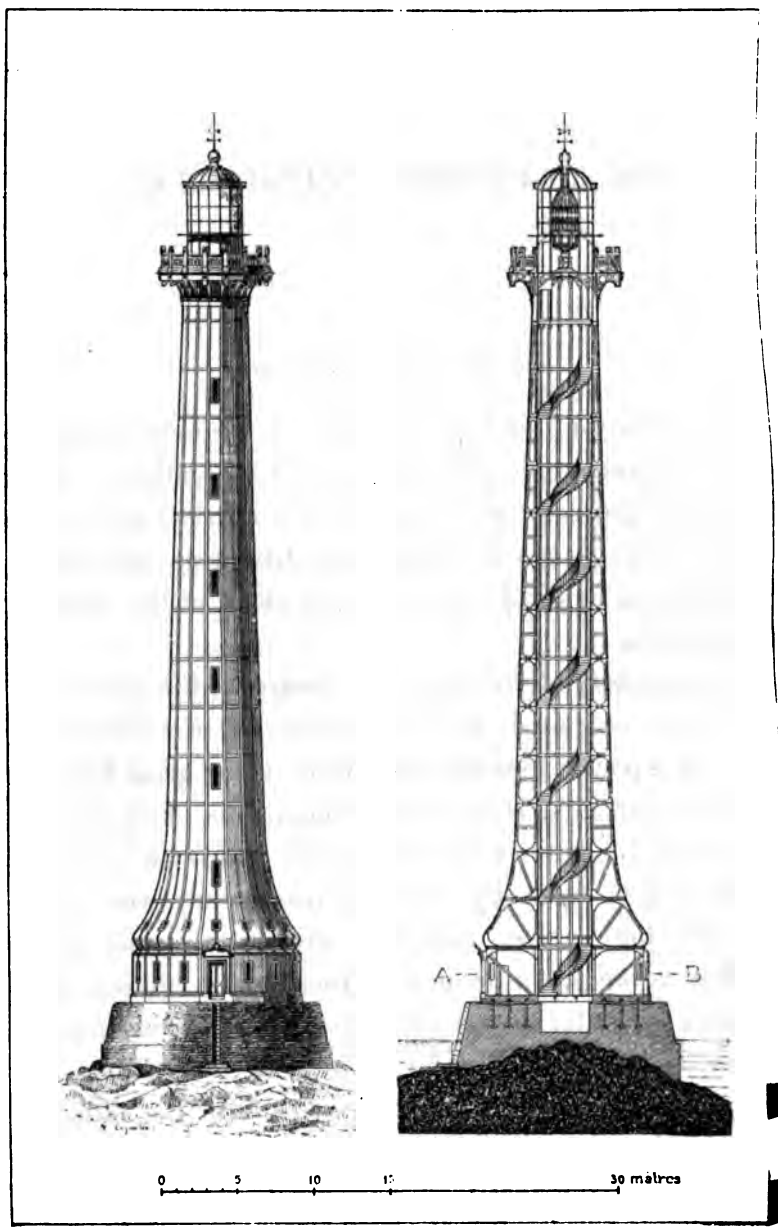
THE ROCHES-DOUVRES LIGHTHOUSE.

(DEPARTMENT OF THE CÔTES-DU-NORD.)

General view of the lighthouse.

The plateau of the Roches-Douvres is the most northerly of those innumerable reefs that render navigation so dangerous on the coats of Bretagne. It is nearly equi-distant between the islands of Bréhat and Guernsey, and about twenty-seven nautical miles from the offing of the harbour of Portrieux.

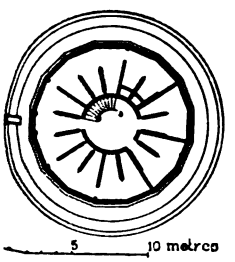
The necessity of erecting a lighthouse on this point had long been recognised, but the construction of a lofty stone tower in a part where the sea, owing to the great force of the tidal currents, is constantly rough, was likely to present many difficulties and consequently to involve a considerable outlay, especially as sailing vessels only were available for the service, and these might frequently make fruitless voyages, on account of their being compelled to cross the currents, both in going and returning. Steam navigation, and the use of iron for purposes of construction, appeared to set these questions at rest, and in the sitting of the 24th January 1862, the Lighthouse Commission decided to illuminate the Roches-Douvres by a flashing light of the First Order.


A
B
0
5
10
30 mètres

The rock upon which it is established is situated near he middle of the south side of the plateau. It rises to the evel of flood-tides, and the stone basement of the edifice is ^{m},10 in height. The iron tower is 48^{m},30, from the foot o the level of the upper platform, and 56^{m},15 to the summit of the lantern. Its diameter, which is 11^{m},10 at the ase for the inscribed circle, diminishes to 4 metres at the op.

The focus of the lighting apparatus is 53 metres above he level of the highest tides.

Cast-iron stairs occupy the centre of the building; the store-rooms and keeper's lodgings are situated in the lower part, and are surmounted by two interior galleries, into which shipwrecked persons can be received, and where the workmen can sleep, when exceptional circumstances necessitate their passing some days in the lighthouse.



Section A B.

The lodgings comprise a room in which are stowed the ater-tanks, a store-room, kitchen, three rooms for the eepers and one room for the engineers, when on a tour f inspection. A coal cellar is contrived in the solid part elow the staircase.

Up to the present time, the majority of iron lighthouses ave been constructed with plates of iron more or less thick, iveted together.

But in the present instance it was not thought expedient to adopt this plan; in the first place, because it causes the stability of the edifice to depend upon a covering greatly

exposed to oxidation, and on this account it is deficient in the requisite conditions of durability, especially if neglected. In the second place, because the riveting and mode of construction require special workmen, and also because the scaffolding necessary is difficult to erect upon a rock of limited dimensions. The following conditions were therefore observed :

1. To render the skeleton of the edifice entirely independent of the exterior covering; to shelter it from the sea sprays which cause rapid oxidation; to facilitate inspection and proper keeping, and to reduce as much as possible the extent of surface exposed to humidity;

2. To manage the process of construction in such a way, that the tower should be erected without scaffolding at the bottom, and without clinching a single rivet on the place.

Stress was also laid upon the necessity of the parts being of such dimensions as to obviate any difficulties of embarkation, of stowage on board, and of placing in position.

Sixteen great uprights or standards, each consisting of fifteen panels in the height, constitute the skeleton or framework of the building. Each panel is in simple T irons, put together, consolidated, and riveted in such a manner as to ensure the most perfect solidarity, and resistance to distortion, contingent upon the strongest shocks or pressures that could be foreseen. These panels are bolted one upon another, and cross-braces, inside as well as outside, also bolted, keep the standards in position. Finally, on the last cross-braces and on the exterior surfaces of the standards are fitted sheets of iron constituting the covering, the joints

of which are protected by wrought iron platbands secured by bolts.

Each standard is surmounted by a cast iron bracket, on which is corbelled out the platform required for the exterior service of the lantern. The standards rest upon large cast-iron soles each of which is held by six wrought iron bolts, and embedded in a solid mass of beton.

The chambers are surrounded by brick partitions; those on the exterior side are $0^m,05$ from the sheet-iron covering in order to afford effectual shelter. A floor in beton raises the surface to $0^m,40$ above the cast iron sole, while the ceiling is in stone-work resting on small iron joists.

The service chamber is at the top of the tower, and communicates with the lantern by a cast iron step ladder, as usual.

The stairs of the tower are in cast iron with wrought iron stringers. The outer stringer is bolted to the standards where it meets them, and thus contributes to the rigidity of the system. A half turn of the stairs corresponds exactly with the height of a panel, that is to say, $3^m,20$.

The entrance door is in oak, with bronze mountings, and all the window frames are in rolled iron.

The T irons are bent according to the angles of the polygon, in order to form the exterior arris of the panels. They are $0^m,18$ by $0^m,10$, and weigh 31 kilogrammes per metre. Those constituting the three other sides of the panels are $0^m,20$ by $0^m,10$, and weigh 35 kilogrammes per metre. The panels of the three first rows have each a diagonal corner bracket arris-wise, formed of a flat bar of iron $0^m,14$ by $0^m,014$, riveted to two T irons $0^m,13$ by $0^m,065$.

This bracket, rivets included, weighs 44 kilogrammes pe metre.

The cross-braces are in flat bar iron, $0^{m},08$ by $0^{m},016$ and weigh $9^{kg},689$ per metre.

The thickness of the plate diminishes from the lowe story, where it is $0^{m},010$, up to the top, where it is re duced to $0^{m},007$.

The cover-plates are formed of plate-iron $0^{m},011$ in thick ness.

The total cost of the construction is indicated in the fol lowing table:

Iron tower, properly so called, wrought iron and castings, 317 328 kilogrammes..	223 986f 76
Joiner's and locksmith's work, bronze hand rail and painting.....	33 788,57
Lantern, lighting apparatus, fog bell....	85 576,21
Packing and carriage.....	19 819,81
Tools, apparatus for erection, various fittings.....	17 086,02
Foundation work and construction.....	225 100,00
	605 357,37

A temporary light was placed upon the tower durin the execution of the work, and was raised at the same tim with it.

The actual light was kindled on the 6th August 1869

The engineers for the iron tower were MM. Léonc Reynaud, Inspector general « des Ponts et Chaussées », di rector of the Lighthouse Service, and Émile Allard, engi neer in chief « des Ponts et Chaussées ».

Constructor: M. RIGOLET, of Paris.

The engineers for the foundation works and the construction on the rock were MM. DUJARDIN and PELAUD, engineers in chief, DE LA TRIBONNIÈRE, engineer, BERTIN, « conducteur des Ponts et Chaussées », and LE BOZEC, « employé des Ponts et Chaussées ».

XVIII

THE FOUR LIGHTHOUSE.

(DEPARTMENT OF FINISTÈRE.)

General view of the lighthouse.

The Four lighthouse is situated on the most advanced rock at the extreme north of the channel of this name, and is two miles west of the little port of Argenton. This rock which is of very hard granite, rises to about 2 metres above the level of flood-tides, and any degree of agitation in the sea renders it inaccessible. In bad weather, the waves break with such violence, that they dash above the lantern of the lighthouse, and have destroyed the shutters of $0^{m},06$ in thickness, which closed the narrow windows of the tower during the execution of the works.

The dépôts and yards for cutting and dressing the stone were established in the port of Argenton, whence the craft which carried the workmen and materials to the rock started when the weather and sea permitted. Steps cut in various places, enabled the workmen to mount the steep and slippery sides, and a crane simple in construction, and offering no hold for the waves, served to land the materials.

The lighthouse consists of a tower, having an interior diameter of $4^{m},50$, and is erected upon a solid mass of masonry levelled to 2 metres above the high tides of the

equinox, and embedded in the rock, the highest points of which it completely envelops. The wall is $2^m,75$ in thickness at the base and $1^m,18$ at the top. The larmier of the upper cornice is supported by sixteen corbels, and above this a parapet consisting of slabs $0^m,20$ in thickness, and joined in pilasters.

Above the solid base, the height of the tower is $22^m,70$, and at this point it is surmounted by a ten sided polygonal structure in sheet-iron which supports the lantern and is $2^m,40$ in diameter. The focal plane exceeds, by 28 metres, the level of the highest tides.

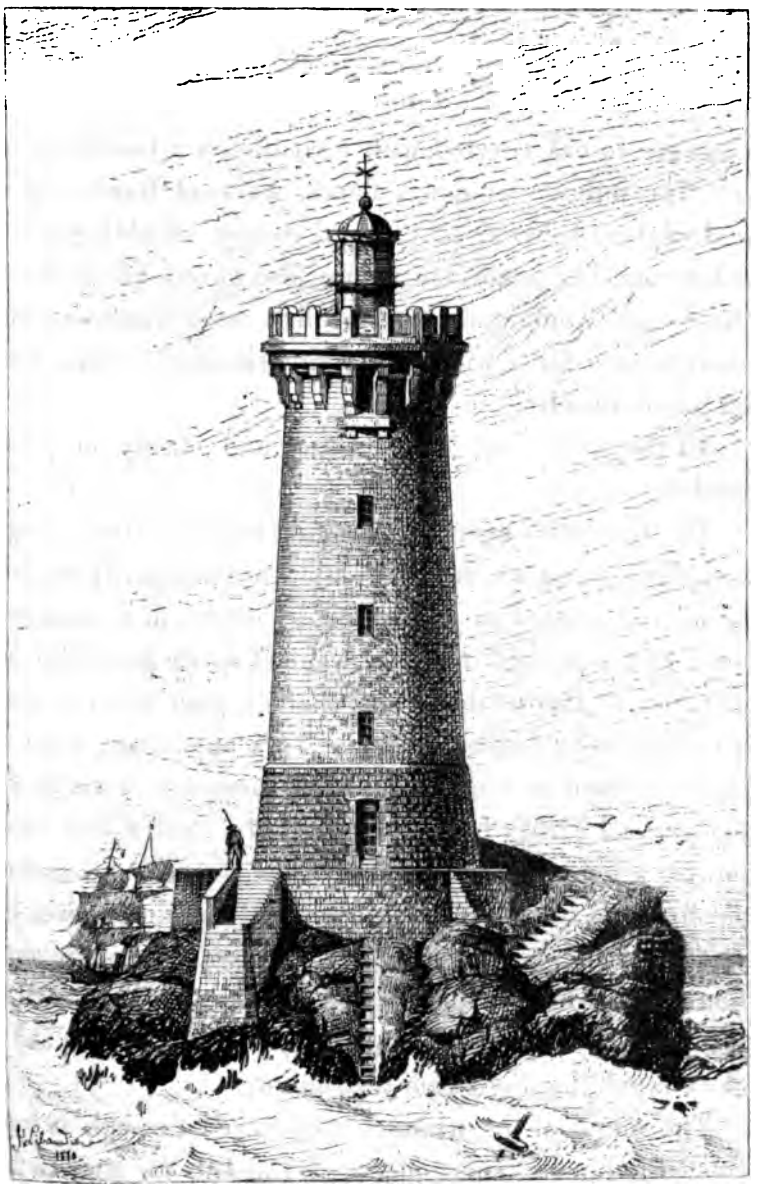
The masonry is in granite rubble, laid in a mortar-bed of Portland cement, and is faced in ashlar with large bonds.

The steepness of the southern declivity of the rock necessitated the greatest precautions in founding the lighthouse. Deep concentric redans were cut into the rock, inclining towards the centre of the tower, and a number of iron gudgeons, $0^m,07$ in diameter, bound the first courses of masonry to the rock. All the stones of the cordon course are also held with iron cramps, and a strong iron band is let in above the corbels of the cornice. The pilasters of the parapet are secured by bronze dies or sockets.

The tower consists of a ground floor and five upper stories. The ground floor, and the four stories above, communicate by stone stairs, commencing at the end of the entrance passage. The stairs are first straight, then circular, with a solid newel, and have ninety-four steps; the staircase is partly let into the thickness of the wall and encroaches slightly upon the cylindrical space of the tower. A

partition of moderate thickness separates it from the chambers. It stops at the fourth story, from which the upper story and lantern are reached by means of wrought and cast-iron hanging ladders, so placed as to occupy little room.

The ground floor is divided into three compartments the vestibule and two paved vaults, each lighted by a dormer-window $0^m,50$ by $0^m,25$. The left vault contains coal cellar capable of containing 5 000 kilogrammes, and which is filled from the stairs; also a force and suction pump for the supply of water. The right vault is the oil room. On the first story is the storeroom in which are twenty-two iron tanks holding 5 000 litres of fresh water; also two coal bunkers containing together 2 000 kilogrammes, and placed on each side of the door, in the angles formed by the projection of the staircase into the interior cylinder of the tower. On the second floor is the kitchen; the stove is placed in a niche above which a deep groove, $0^m,30$ in breadth by $0^m,45$ in depth, is formed in the wall and extends to the upper platform. In this groove is fixed the copper chimney-pipe of the stove. The flat corners of the projection of the staircase are utilized as two cupboards. The third story is the bedroom, in which are two beds and two cupboards, similar to those in the kitchen. On the fourth floor is the steam-trumpet room, which is above the service room on the fifth story. The ground floor and the two first stories are vaulted, as is the fifth; the former cylindrically, the latter spherically. They are all in Bristol bricks except that of the fifth floor which, being pierced by the service stairs, is entirely in granite. On the third and fourth stor



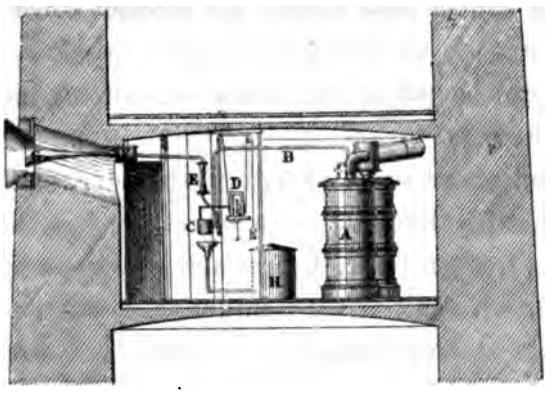
ies, with the view of gaining space, a framing, consistin of seven iron plate girders cross-braced, has been substi tuted for the vaulting, and supports small brick arches.

The entrance door of the lighthouse and the outer win dows are in oak covered with a coating of a boiled linsee oil. The interior windows, floors, wainscot frames, roon and cupboard doors, plinths and cornice mouldings are o oak waxed. The panels are of pine, also waxed. The frames o the dormer windows and the two first outer windows of th staircase are fitted with dead-lights similar to those use on board vessels.

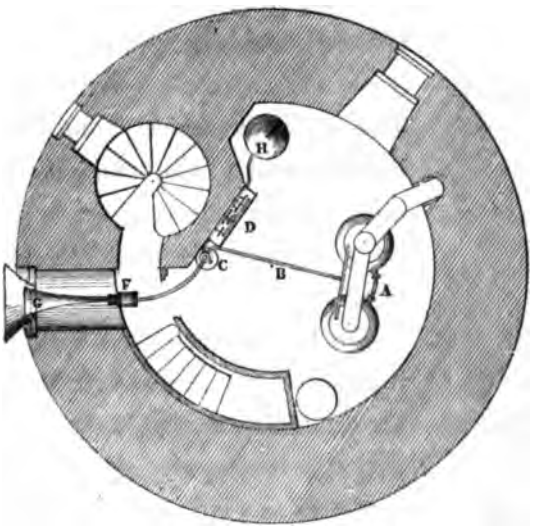
All the metal work is in bronze, and mostly on specia models.

The trumpets, to which recourse is had in time of fog and when the light is scarcely visible, are ordinarily sounde by air compressed in a reservoir by means of a steam-en gine. In the present instance, want of space precluded th adoption of this method, and another plan was followed invented by Professor Lissajoux. This apparatus, which i clearly shown in the two drawings annexed, consists of two vertical Field's boilers coupled, of a total of four hors power; a trumpet with apparatus for producing a rush o air by a jet of steam; a distributing machine moved b steam, opening and shutting at intervals the communica tion of the boilers with the trumpet, so that the sound produced at the rate of one blast per five seconds; and clock regulating the steam distributor.

The sound of the trumpet is conveyed through an ir cone, fixed in a circular opening formed in the west-sout west side of the tower wall. The smoke of the fuel issu



Vertical section.



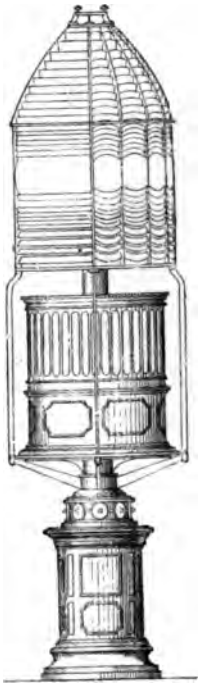
Plan.

A. Coupled boilers.
B. Steam-pipe.
C. Steam-cock.
D. Clockwork moving this cock.
E. Air apparatus.
F. Trumpet.
G. Bell of trumpet.
H. Condenser.

Scale of $0^{m},001$ to 1 metre.

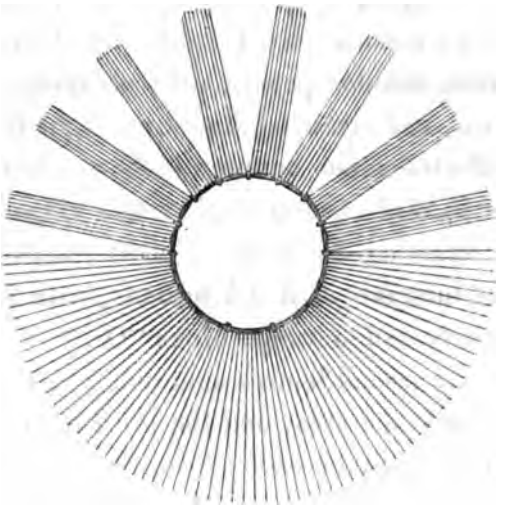
through a copper pipe joining the kitchen stove pipe, in the groove made for that purpose. The necessary pressure of steam can be got up in twenty minutes at most, after lighting the fires.

The boilers are supplied with fresh water, and the consumption, with the rhythm adopted for the trumpet, is about 25 litres per hour. A force and suction pump, placed in the western vault of the lighthouse, pumps fresh water from boats moored alongside the rock, and discharges it into the twenty-two iron tanks placed in the first story. These tanks hold 1 500 litres, intended for the keepers, and 3 750 litres for the boilers, which are thus provided with sufficient water for one hundred and fifty hours of work at least, without the supply being renewed. The water is raised from the tanks to the reservoir in the trumpet chamber, by means of an injecting apparatus worked by a steam-cock attached to the boilers.



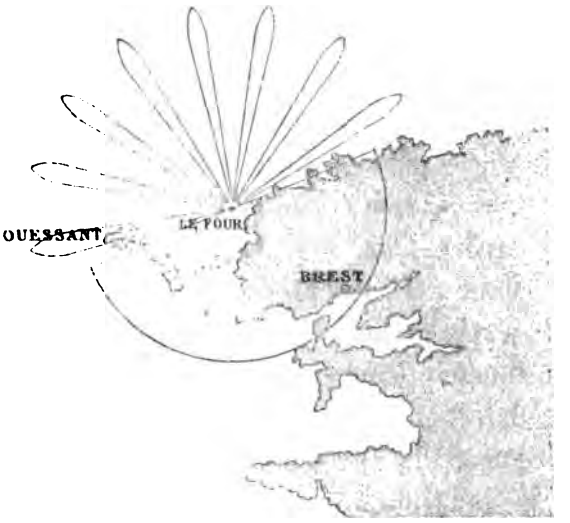
On the western coast of Finistère the lights are numerous, in proportion to the difficulties and importance of the navigation in these parts, and it was therefore essential to give to the Four light a distinctive character which should prevent its being mistaken for any other.

The lighthouse is provided with lenticular apparatus of the Third Order illuminated by a lamp with three wicks, and consists of two



Plan indicating the direction of the luminous rays.

Scale of $0^{m},01$ to the metre.



Curve of the ranges.

Scale of $0^{m},005$ to 4 nautical miles.

parts, each occuping a half circumference. One of these parts shows an ordinary fixed light; the other comprises eight complete annular panels, each occuping 1/16 of the circumference, and arranged to produce eight flashes. The rotation is effected in one minute and shows, during 30 seconds, a fixed light of 224 burners hoving a range of $16^{mm},7$; during the following 30 seconds, eight successive flashes are shown at intervals of 3 3/4 seconds, with an intensity of 940 burners and a range of $21^{mm},6$.

The first and second figures annexed, give the elevation and plan of the apparatus, and the third the curve of the ranges, and it is only necessary to make the latter revolve on its centre, and the nature of the light as it appears to navigators, will be easily comprehended; it is designated as a fixed and flasi ng light.

The cost of the construction amounted to 256 000 fr. not including the steam trumpet, the expense of which was 31 000 francs, and the optical apparatus which cost 22 000 francs. The total measurement of the masonry of th tower being 920 cubic metres, the outlay did not exceed 280 francs per cubic metre.

Notwithstanding the perilous nature of the conditions under which the work was executed, no loss of life occurred during the whole period of time occupied in the construction. Unfortunately some serious disasters have taken place since that date; on the 27th April 1873, in fine weather, a boat lying near the rock was carried away and upset by a heavy swell, and three workmen in her were drowned. On the 2nd November 1876, one of the keepers, named Wimel, was on the outer platform, where he was fastening the rope for

disembarking, and though at an elevation of 4 metres above the level of the water, he was washed off the platform by a similar wave and borne away by the current, while his comrades were looking on, unable to help him.

Other accidents have happened, fortunately not attended with fatal results, but which clearly show the dangerous character of the sea at this point. In the early part of December 1874, the sea broke in the lighthouse door and carried away a great part of the ashlar flagging of the outer platform which was bedded in pure cement and cramped with heavy bars of iron. On the 9th March 1876, the sea broke the glass of the lantern, and some of the splinters flew against the apparatus; upon this occasion, the keepers manifested great courage and presence of mind, for they succeeded in saving the apparatus from destruction, and in replacing the glass in the face of a tremendous gale, while great masses of water were dashing up to the lantern.

In tempestuous weather with the wind at N. W., the lighthouse literally disappears in the foam, and it may be said that the sea is heavier at this spot than at any point on the coast of Bretagne. Nevertheless, the construction of the lighthouse did not present such formidable difficulties as that of Ar-Men, and this may be explained by the fact that the heavy waves are not so continuous, and in addition to this, the rock is nearer the shore.

The lighting apparatus was made by MM. Henry-Lepaute and son.

The plan of this apparatus was designed under the direction of M. Léonce Reynaud, Inspector general, by M. Émile Allard, engineer in chief « des Ponts et Chaussées », with

the assistance of M. Denechaux, principal « conducteur » doing duty as an engineer.

The building was planned and executed by MM. Planchat, engineer in chief « des Ponts et Chaussées », and Fenoux, engineer. The works were directed by M. Bouillon, « conducteur ».

The steam-trumpet was planned by MM. Lissajoux and Flaud.

XIX

THE AR-MEN LIGHTHOUSE.

(DEPARTMENT OF FINISTÈRE.)

The island of Sein is situated on the western extremity of the department of Finistère and extends in a westerly direction to a distance of nearly 8 miles, by a succession of reefs which lower proportionally to their distance from the island. The tops of some rise above the highest tides; others are alternately above and below the surface of the water, while the greater number are always submerged. They constitute a sort of barrage, the direction of which is nearly perpendicular to that of the tidal currents, and the sea almost constantly breaks over them with extreme violence.

This singular geological formation is known by the name of the Sein Causeway; it has acquired a sad celebrity amongst nautical men, and in 1825 it occupied the attention of the Commission appointed to elaborate our system of maritime lighting.

The plan adopted, and at that time it was impossible to propose a better, consisted in erecting two lighthouses of the First Order : one on the Raz Point, the other on the island of Sein, to mark the direction of the causeway. Mariners are clear of danger, and know on which side they are,

when the lights open out from each other. On the other hand, when these luminous points are nearly in the same line, it warns them to make a greater offing, to avoid striking on the reefs. But nothing enabled them to judge of this distance, and it does not require a very thick fog to prevent the lights from effectually indicating the limit of danger, and in such a case they are of little use. For this reason the Sein Causeway continued to be the scene of mournful disasters, and the former system of lighting had only the effect of reducing the number of wrecks, while our navigators for whose security so many precautions are now taken at other parts of the coast, complained at different times of this state of things.

In April 1860, the Lighthouse Commission demanded that the subject should be properly investigated, in order to know if it would not be possible to erect a lighthouse of the First Order on one of the rocks not covered by the sea and as near as possible to the extremity of the causeway. The idea was approved on the 3rd June following, and the first surveys of the locality were confided to a commission composed of engineers and officers of the navy. In July of the same year, this commission had made a careful examination of the local conditions, and had ascertained that the heads of three rocks emerge from the water near the extremity, even at high tides. Of these rocks, which bear the names of Madiou, Schomeur and Ar-Men, the two first are nearly covered, while the third rises to about $1^{m},50$ above the lowest ebb-tides. The state of the sea had not permitted them to go alongside Ar-Men, but its dimensions appeared insufficient for the construction of a great lighthouse, and it

appeared impossible to land, however favourable the weather might be. The commission therefore concluded by proposing as a site, the rock Neurlach, which is situated 5 miles inland from the extremity of the causeway. This idea was repudiated by the Lighthouse Commission, as not tending to ameliorate the existing state of things sufficiently for the requirements of navigation, and the Ministry of Marine was requested to command a thorough hydrographic exploration of the extremity of the causeway.

Various circumstances retarded the execution of this work. In 1866, M. Ploix hydrographer was sent to the spot, and if he was not able to gather all the information that could be desired, his investigations at least enabled the Commission to decide upon a plan. M. Ploix arrived at the conclusion that Ar-Men was the most proper site. « It is a work, » said he, « exceedingly difficult, almost impossible, but considering the paramount importance of lighting the causeway, we must try the impossible. »

The currents passing over the Sein Causeway are in fact most violent; their speed in high tides exceeds eight knots, and in the calmest weather they cause a strong chopping sea, and render the water very rough as soon as a breeze from an opposite direction meets them. There is no land to shelter the rock against winds from between the North and East-South-East, round to the South, and it is only possible to go alongside during very gentle winds between North and East.

To anchor a floating light at the extremity of the causeway had been recognized to be impossible, as much on account of the great depth of water, as in respect of the

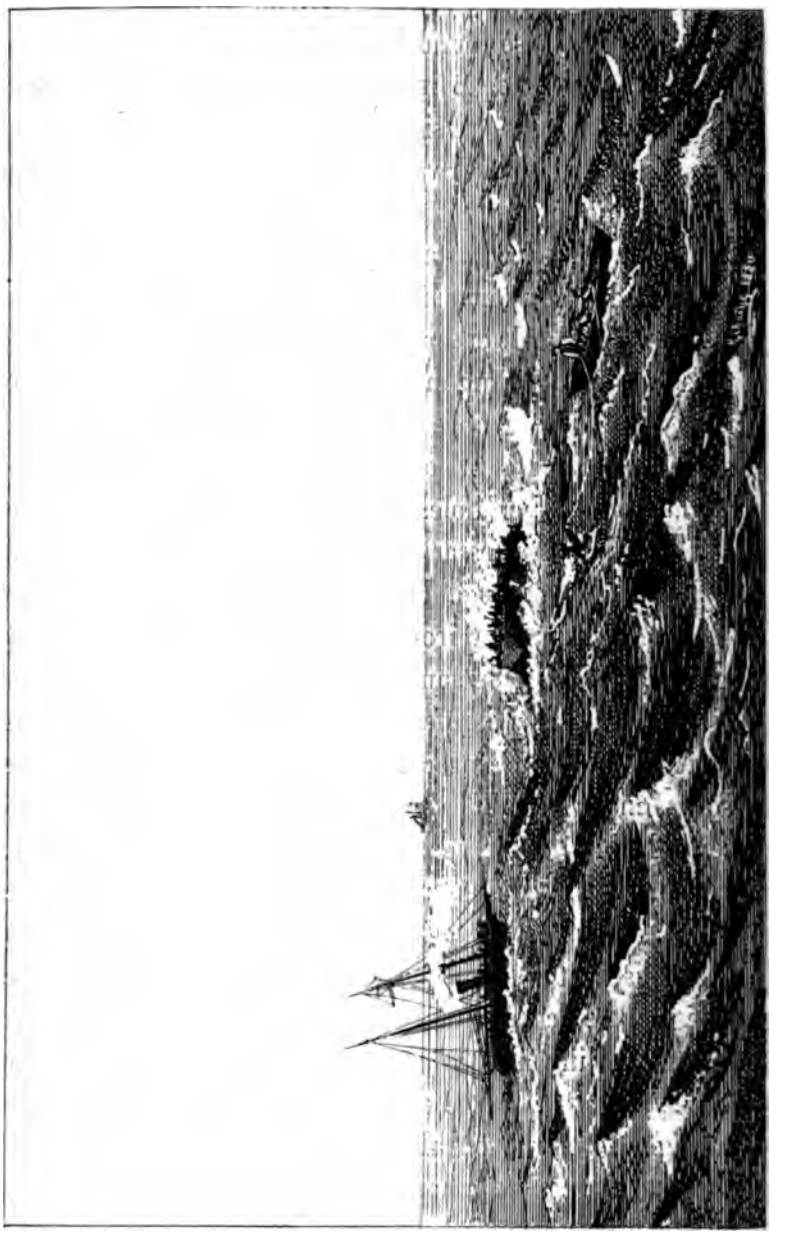
bottom being thickly studded with rocks, around which the holding cable would be fouled.

Neither was it possible to entertain the idea of establishing an iron structure resting directly on the reef, since boring holes $0^{m},18$ or $0^{m},20$ in diameter, necessary for embedding and securing the standards, would be one of the longest and most difficult operations. With regard to the rock, it was also observed that the principal planes of cleavage were vertical, and fears were entertained that the base might not possess the solidity requisite to sustain the shocks it would have to support; besides which it would be almost impossible to land the different pieces of the iron framing, necessarily heavy and difficult to handle, and there would be the risk of losing several before succeeding in putting them in position. Taking into account these various considerations, the Lighthouse Commission, in its sitting on the 29th November 1866, gave an opinion that a solid foundation of masonry must be established on the rock Ar-Men, and that it must be of such dimensions as would be suitable for the ultimate construction of a lighthouse.

Neither the Commission of 1860, the engineer hydrographers, the engineers of the department, their sailors, nor the director of the Lighthouse Service had hitherto succeeded in landing on the rock. M. Ploix had not been able to get nearer than 15 metres; but M. Joly, engineer, had been fortunate enough to get alongside the rock, and the sketches that he made, and afterwards finished from the descriptions of the fishermen of the island of Sein, gave the starting point of a system of constructions. The dimensions of the rock were ascertained to be 7 or 8 metres

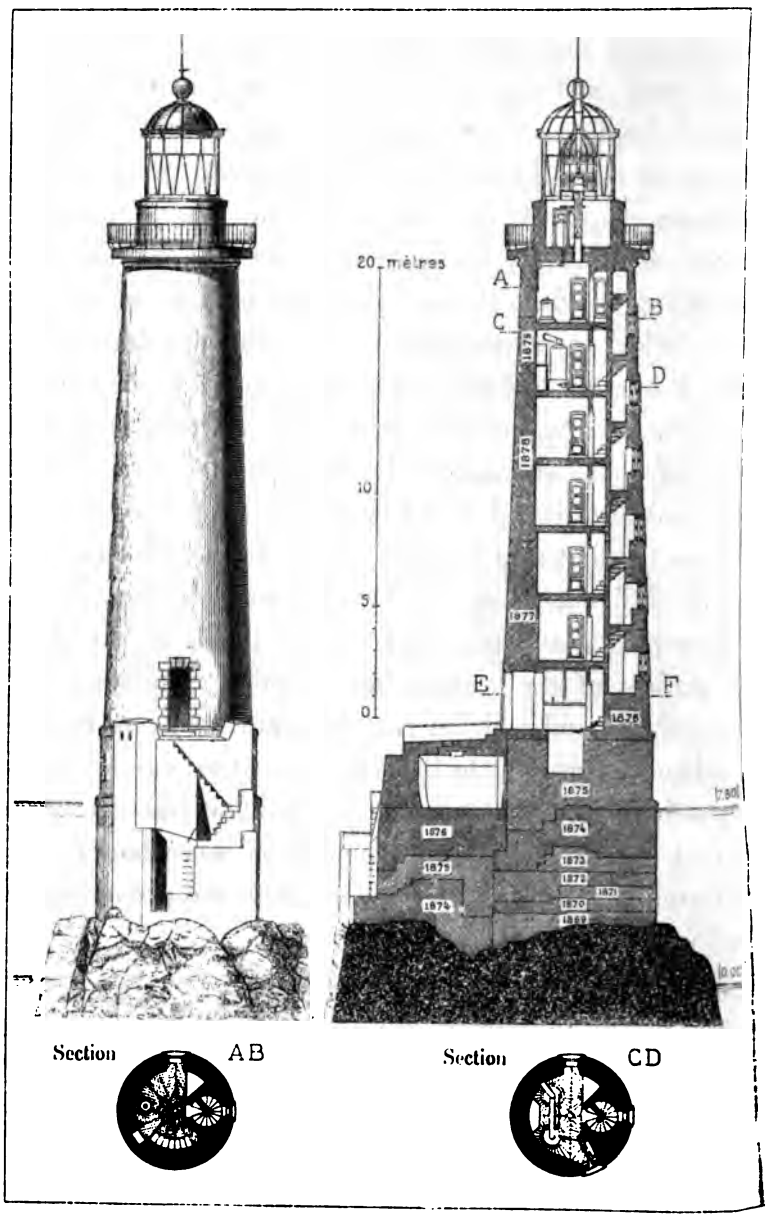
n breadth by 12 to 15 metres in length, at the level of bb-tides; it was also found that the surface was very unequal and divided by deep fissures, and that while almost perpendicular on the eastern side, there was a gradual slope on he western. Shortly afterwards, the syndic of the seafaring slanders announced that a fresh attempt, made by him nder favourable circumstances, had met with success, and ie forwarded a specimen which showed the rock to consist of a gneiss tolerably hard, except in some parts where it was decomposed. The following mode of construction was therefore decided on, viz., to bore holes 30 centimetres in depth, and one metre apart, all over the site of the intended edifice, and some other holes outside this limit, in order to hold the ringbolts necessary for craft coming alongside, and for making fast the guys. The object of the first set of holes was to receive wrought iron gudgeons, to fix the masonry to the rock, and at the same time to make the construction itself serve to bind the different parts and fissures, and thus consolidate a base the precarious nature of which gave rise to some misgivings. It was proposed that in addition to these gudgeons, other vertical gudgeons should be added, and strong iron chains introduced horizontally into the masonry, in proportion to its progress, so as to prevent any possible disjunction. For the work of boring the holes, the services of the Sein fishermen were called into requisition, since their calling familiarized them with all the rocks of the causeway, and they were consequently in a position to take advantage of every favourable opportunity. After many difficulties, they accepted a contract, the Government agreeing to furnish tools and life-belts.

14.



In 1867 they took advantage of every opportunity and went to work vigorously. Two men from each boat landed on the rock, and provided with their cork belts lay down upon it, holding on with one hand and using the jumper or hammer with the other, they worked with great energy, the waves constantly breaking over them. When a man was carried off the rock, the violence of the current bore him a long distance from the reef, against which he would have been dashed to pieces, but his life-belt kept him afloat, and a boat went to fetch him back to work. At the close of the season seven landings had been effected, and eight hours of work accomplished, during which time fifteen holes had been bored in the highest part of the rock, and this was the first step towards success. In the following year greater difficulties were to be encountered, since it was necessary to commence work on the points hardly above the surface of the water; but valuable experience had been gained, and a higher rate of remuneration gave additional encouragement to the fishermen; the season was favourable, sixteen landings were effected and eighteen hours of work accomplished, forty new holes were bored, and they even succeeded in partially levelling and preparing the work for the first course of masonry.

The construction, properly so called, was undertaken in 1869. The galvanized wrought iron gudgeons, $0^{m},06$ square and 1 metre in length, were fixed in the holes, and the masonry was commenced with small uncoursed rubble and Parker-Medina cement. In fact, a cement of the most rapidly hardening character was essential, for the work was carried on in the midst of waves breaking over the rock,



Ar-Men Lighthouse.

and which sometimes wrenched from the hand of the workman the stone he was about to lay. An experienced sailor, with his back against one of the points of the rock, was always on the watch to give warning of such waves as were likely to sweep the rock, when the men would hold on, head to the sea, while it washed over them. On the other hand, when he announced a probable calm, the work went on with great rapidity. All the workmen were supplied, as the fishermen had been, with life-belts, and esparto shoes, to prevent slipping. The « conducteur » also, and the engineer, who by his presence always encouraged the workmen, were similarly furnished.

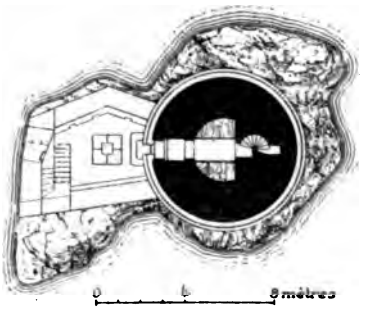
Every opportunity presented by an exceptionally calm state of the sea was promptly embraced, and a small steam sloop with the landing boats in tow and carrying the workmen and the requisite quantity of materials for a tide's work, started from the island so as to arrive in sight of the rock at about four hours of ebb. But the calm weather could not be always calculated upon, and the day was sometimes lost. When a landing was practicable, the stones and small bags of cement were landed by hand, and care was taken to axe the surface of the masonry before commencing a new course. It is unnecessary to add that the cement was employed pure, and mixed with sea-water; fresh water was not used till 1877, when the construction had reached the parts that were to be inhabited. At the close of the season of 1869, twenty-five cubic metres of masonry had been executed, and these were found intact the following year.

At the present date, the contents of the masonry are $859^{m},65$ cubic metres and the tower is 22 metres above

the highest tides. The success of the undertaking is therefore assured, and the lighthouse will be finished in 1881.

Since 1871, Portland cement has been substituted for Parker, the resistance of the former to the decomposing action of sea-water being ascertained to be superior to that of the latter, and the stone-work at the foot of the building will be preserved by refilling the interstices with it and perhaps by a continuous covering of the same material.

From experiments upon the cohesive qualities of the mortar and the stones found in the vicinity, it was observed that the amphibolic or hornblende rock of Kersanton was superior in this respect, as in many others, and it was therefore exclusively employed in the execution of the masonry. The facing stones are scappled, while those for the filling in are as they come from the quarry, and all are of small dimensions. The galvanized wrought iron gudgeons, tie-bars, and bands, are deeply embedded in the stone-work in order to prevent disjunction.



Section AB.

According to the project recently adopted, the light will be of the Second Order, with a flashing light, and the focus will be elevated $28^{m},80$ above the level of the highest tides. This limit might have been exceeded, so as to admit of a light of the First Order, but for the insufficiency of the base, and it was necessary above all things to ensure the stability of the edifice. The solid part constituting the basement is continued with

the diameter of $7^{m},20$, up to the level of high tides, and with that of $6^{m},90$ for the three following metres. The limited extent of the rock necessitates these dimensions. The interior diameter of the chambers varies from 3 metres in the lower to $3^{m},40$ in the upper part, by means of successive offsets, and the thickness of the wall diminishes from $1^{m},70$, at the level of the entrance door, to $0^{m},80$ below the cornice of the crown. There will be seven stories in the edifice, one of which will be devoted to a sounding apparatus intended to indicate the position of the lighthouse during a fog.

YEAR.	OF LANDINGS	OF HOURS. PASSED on the rock.		CUBE OF MASONRY executed			ANNUAL PROGRESS IN THE HEIGHT OF THE TOWER.	TOTAL HEIGHT, of the end of each year.		OUTLAY per year.	COST per cubic metre.
		per year.	per landing.	per year.	per landing.	per hour.		above the rock.	above the highest tides.		
										francs.	francs.
1867...	7	$8^{h},00^{m}$	$1^{h},8^{m}$	"	"	"	"	"	"	8 000	
1868...	16	18 ,00	1 ,8	"	"	"	"	"	— $4^{m},40$	21 005	2 156
1869...	24	42 ,10	1 ,45	$25^{m},05$	$1^{m},04$	$0^{m},60$	$0^{m},60$	$0^{m},60$	— 3 ,80	25 000	
1870...	8	18 ,05	2 ,15	11 ,55	1 ,44	0 ,64	0 .60	1 ,20	— 3 ,20	26 336	2 289
1871...	19	22 ,10	1 .50	23 ,40	1 .95	1 .05	0 ,60	1 ,80	— 2 ,60	17 000	726
1872...	13	34 ,20	2 ,38	54 ,55	4 ,20	1 ,62	0 ,60	2 ,40	— 2 ,00	40 000	727
1873...	6	15 ,25	2 ,34	22 ,00	3 ,67	1 .43	0 .40	2 ,80	— 1 ,60	62 000	2 818
1874...	18	60 .10	3 ,20	115 ,30	6 .41	1 ,91	2 .00	4 ,80	+ 0 .40	71 800	623
1875...	23	110 ,55	4 ,49	203 ,00	8 ,83	1 ,82	3 ,00	7 ,80	+ 3 ,40	76 000	375
1876...	23	162 .45	7 ,05	128 ,00	5 ,56	0 ,78	3 ,20	11 ,00	+ 6 ,60	80 000	625
1877...	30	261 ,00	8 ,42	120 ,00	4 ,00	0 .46	5 ,70	16 ,70	+ 12 ,30	90 000	750
1878...	30	207 ,30	6 ,55	125 ,00	4 ,16	0 ,60	7 ,20	23 ,90	+ 19 .50	100 000	800
1879...	*10	62 ,00	6 .12	31 .80	3 ,18	0 ,51	2 ,50	26 .40	+ 22 ,00	120 000	3 773
TOTALS and AVERAGES.	220	1,022 ,30	4 .39	859 ,65	3 ,91	0 ,84	2 .40			737 136	857

* Exceptionally bad weather prevailed during the summer of 1879 and the season was very unfortunate.

The former table, while reproducing some of the figures already given, shows the principal facts relating to the works executed, commencing from 1867.

An examination of this table will give some idea of the paucity of the number of working days, and to what extent the influences of the sea and weather predominate here, since in the year 1869, at the commencement of the building, and when the landings were attended with the greatest difficulty, it was possible to go on the rock more frequently than in either of the seven succeeding years, and this notwithstanding the fact that the progress of the work every year augmented the facilities for landing.

The table also presents the various phases through which the construction passed.

In 1874, it was possible to establish a derrick for unloading the materials. The building had then attained a height that permitted the workmen to remain on the rock longer at each tide; it also rendered the work easier and less dangerous, while the filling in masonry had yet to be executed and was not difficult to accomplish. Consequently in 1874 and 1875 the work progressed at the rate of nearly 2 cubic metres per hour, and the average cost which amounted in 1873 to 3 800 francs per metre, was diminished in 1875 to 375 francs.

Dating from 1876, the conditions of landing and remaining at the work continue to improve, but the height to which it is necessary to hoist the materials keeps on increasing, and the masonry of the upper part of the tower occupies much time on account of the difficulty of fixing the apparatus and of employing a large number of workmen in so limited a space.

The results of the years 1876 and 1878 are attended with new conditions. The number and duration of the landings exceeded those in the preceding years, but the work executed per hour is not more than from $0^m,46$ to $0^m,60$ cubic metres while the average cost rises to 750 and 800 francs.

In respect to the year 1879, it was very unfortunate. During the whole summer the weather was exceptionally unfavourable, and only 31,80 cubic metres of masonry were laid, the price of which per metre amounted to a considerable sum. The average cost since the commencement of the work is 857 francs.

Supposing that the price is calculated per metre of the height of the tower, it amounts to about 28 000 francs, while until the construction of the edifice at Ar-Men, the average cost of other French lighthouses in isolated positions in the sea, was only 11 000 francs.

The drawing exhibited represents the tower as it will appear when finished, and shows the state of the masonry down to the present day.

This work was conceived and planned in what is essential by M. Léonce Reynaud, Director of the Lighthouse Service. In the first instance it was carried on under the direction of M. Planchat, engineer in chief, and afterwards under that of M. Fénoux, engineer in chief, by MM. Joly, from 1867 to 1868; Cahen, from 1869 to 1074; Mengin, from 1875 to 1877 and de Miniac since 1878. The superintendance of the working arrangements was confided to M. Lacroix, principal « conducteur » in 1869 and 1870, and to M. Probesteau, « conducteur », since 1871.

It is be regretted, since it would only be an act of simple justice, that to this list cannot be added the names of those brave sailors and Breton workmen, who, unconscious of their claims to admiration, have, by dint of energy and earnestness of purpose, ensured the success of an entreprise, bolder and it may be said, more daring that any preceding undertaking of the same character.

XX

THE LAVEZZI BEACON TOWER.

(DEPARTMENT OF CORSICA.)

The Lavezzi rock is a source of great danger to navigation and is situated in the Straits of Bonifacio, between Corsica and Sardinia; it is 1 800 metres S. of the island of Lavezzi (France) and 7 000 metres N. W. of the island of Razzoli (Sardinia). The upper part forms an inclined plateau on which may be described a circle with a diameter of $6^{m},50$ and the depth of water varies from $2^{m},30$ to 6 metres at average tides. On the N. W. side the rock is perpendicular for about 8 metres.

This rock, submerged and situated in the middle of the channel, is directly in the route taken by vessels and had been the cause of many fatal disasters, the most appalling of which was the wreck of *the Semillante*. This frigate sailed from Toulon on the 14 February 1855, under the command of captain Gabriel Jugan; she was bound for the Crimea, and had on board 400 soldiers and a crew of 350 men. On the morrow she was passing through the Straits of Bonifacio, in the midst of a tempest so fearful that the recollection of it lives yet in the memories of the mariners of Bonifacio. What happened then no one can tell, but there is little doubt but that the ship struck the rock and was afterwards driven on to the cliffs of Lavezzi; the fragments of the rudder found on the rock sufficiently corroborate this

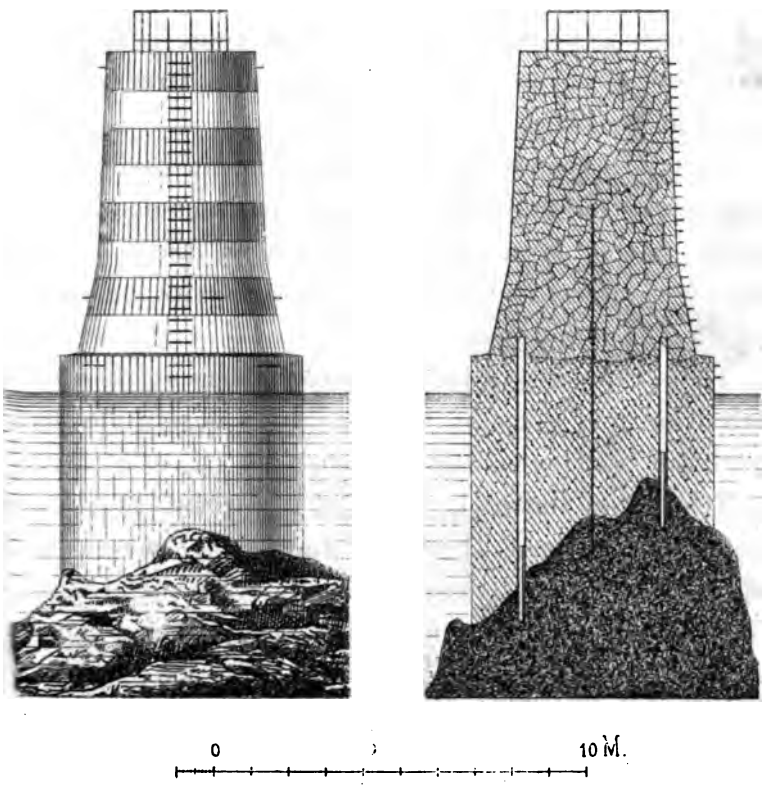
statement. No person escaped, but 592 mutilated corpses were washed ashore, and among them that of the captain, the other bodies were never discovered.

In order to prevent the recurrence of similar disasters, it was considered imperative to take measures for warning mariners from so dangerous a rock, and this result is now attained.

During the night the position of the rock is indicated by the intersection two luminous sectors of red light proceeding from lights established on the islands of Lavezzi and and Razzoli. During the day it is indicated by a stone tower the building of which was commenced in 1876 and finished in 1877. The drawing exhibited, represents this tower.

The execution of the work was attended with the greatest difficulties; for as already stated, the rock to be indicated is 1 800 metres from the almost desert island of Lavezzi and 12 kilometres from Bonifacio, a place offering no resources either in special workmen or in materials. It was necessary to freight boats and gondolas at Ajaccio; the cement, the iron and all the materials had to be brought from France by a steamer which performs the service from Ajaccio to Bonifacio only once a fortnight. But the most serious obstacles to be encountered, consisted in the force of the currents prevailing almost continuously in the Straits of Bonifacio, and in the extreme uncertainty of the state of the sea, even during the summer. The violence of the waves and the failure of previous attempts gave rise to the graves apprehensions on the part of the engineers, and amply justified the special nature of the precautions they believed in incumbent upon them to adopt, as will be seen presently

The foundation is formed of a solid cylindrical mass of cement beton, $6^{m},50$ in diameter, levelled to 1 metre above average tides; the form of the tower is that of a truncated



cone 6 metres in height, the bases of which are respectively $5^{m},50$ and 4 metres in diameter.

The adhesion of the tower to the rock was augmented by means of twelve iron gudgeons; the four nearest the centre of the solid part are $0^{m},10$ in diameter and penetrate $0^{m},60$ into the rock; the eight others are $0^{m},15$ in diameter, and are bedded in to a depth of 1 metre.

The work may be divided into four periods: the preparation, the foundation, the boring of the holes in the rock, and the construction of the tower above the water.

In the month of April 1876, the building of the workmen's huts was commenced in the lighthouse inclosure on the island of Lavezzi. The materials were ordered and prepared at Marseille.

On the 1st June all the personnel, men and boats, landed at Lavezzi, the materials necessary for commencing the works having been previously conveyed there; a large supply of cement had arrived from France with the mason's labourers and the divers.

The personnel consisted of the « conducteur » of the works two divers and a guide, two masons' labourers and four workmen, seamen as well as labourers.

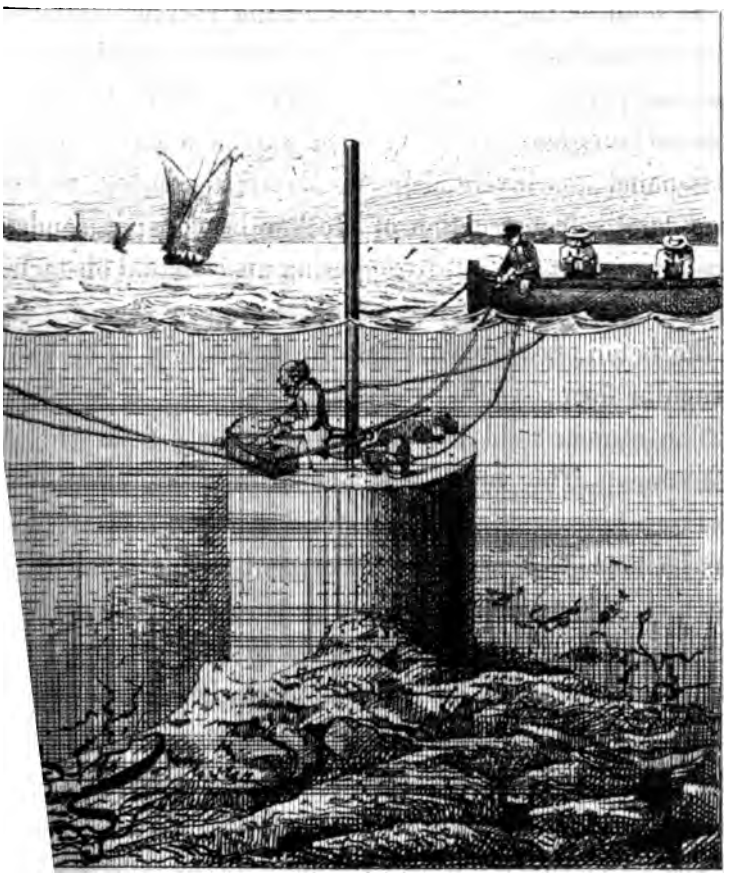
The floating material comprised two tartans of 22 tons each and three boats of different dimensions, one of which carried the diving apparatus. For the transport of the various things required, a fourth boat was employed between Lavezzi and Bonifacio.

Four moorings were immediately laid and attached to sheet-iron buoys placed N. W., W. S. W., S. E and E. N. E. of the rock, in such a manner as to constitute a mooring of the greatest security.

The clearing of the rock occupied the 5th and 6th of June, but this operation was interrupted by bad weather and could only be resumed on the 25th and on the 28th when it was finished. It will therefore be observed that the month of June was very unpropitious, and the season commenced unfavourably.

When it was not possible to land on the rock, all the orkmen were employed in breaking stone for the beton.

On the 5th July the centre of the foundation was marked ith all possible accuracy, and a bar of galvanized iron



in diameter, was bedded in with pure cement, after he running in of the beton was commenced. This was in tubs to the diver, who emptied and returned nd rammed down each successive lot of beton upon

the preceding one. Twelve holes were made in the solic part, by the aid of cast-iron tubes $0^m,60$ in height, fittin $0^m,15$ into each other, and laid successively according t the progress of the foundations.

As soon as the highest point of the rock was attained and the foundation was brought to a surface nearly level, movable panel was employed; it was $0^m,60$ in height an occupied in plan, about the 1/5 part of a circumference. This panel was invented by M. MARTIN, engineer, and was used for the construction of the Var beacons; it rendered most important service, by opposing an effectual obstacle to the current, and preventing the watering or carrying away of the beton, besides enabling the foundation to be laid in a regular form.

The cement used in the foundation was from the Mediterranean. The beton was formed in mass, in the proportion of one part of broken stone to one of mortar, which was itself made of two parts of cement to one of sand. For the rest, this proportion of mortar varied, according to the force of the current and the particular part of the foundation Thus, externally, the cement was used without any mixture of stones, and sometimes pure, in order that it migh harden more rapidly, while in the interior, the beton almos always consisted of equal parts of cement, sand and stones

The state of the sea frequently interrupted the operations Many times the workmen went to the rock and were compelled to leave it after an hour's work, and sometimes without having been able to work at all.

On several occasions it happened that after being employed for two days, eleven or twelve days would follo

during which nothing could be done; eleven interruptions of this kind were experienced. On the 25th August, a dreadful storm prevailed in the Straits of Bonifacio, and sixteen days elapsed before the sea was sufficiently calm to permit the work to be resumed. The unforeseen expenses incurred will be readily comprehended.

At length, on the 30th September, the foundation was raised to 1 metre above the average level of the sea. In one hundred and seventeen days, scarcely thirty-six daya' work had been accomplished, at an average of six hours a day. The measurement of the solid foundation was 163 cubic metres; but by taking advantage of a fissure in the south-eastern part of the rock, it was found possible to erect a counterfort to the tower, of about 14 cubic metres in dimensions, which increases the total to 177 cubic metres.

At this period the works might have been stopped, and the operation of boring the holes in the rock deferred till the following summer. But this difficult work required a whole season, and in that case the tower could not have been finished before 1878. So that a year was gained by commencing the boring immediately, and this advantage only cost about 7 000 francs.

The operation was effected by means of borers worked in tubes, contrived for this purpose in the solid foundation; and when the hole reached the depth required, a galvanized iron gudgeon, about $0^m,01$ less than the diameter of the hole, was lowered into it; the length of the gudgeon was double the depth of the hole, and the tube was afterwards filled with pure cement very liquid.

The total depth of the different borings is $10^m,40$, and

the operation was commenced on the 27th October 1876, a finished the 7th August 1877. As might have been expecte it was frequently interrupted by the sea, but it ought to stated that the weather was exceptionally bad that ye Thus, hardly eleven days work were accomplished during month, with an average of seven hours and ten minutes day. The average boring was at the rate of $0^{m}0,14$ per ho of actual work, a very satisfactory result, considering t circumstances under which the operation was effected, a the extreme hardness of the rock.

On the 8th August the construction of the tower w commenced, and on the 14th September following it w finished, including the balustrade. It is in cement masonr faced with pargeting, $0^{m},02$ thick, also in cement. Th latter operation presented no peculiarity worthy of notic and occupied one hundred and fifty hours of actual wor The measurement being 113 cubic metres, the avera work was at the rate of 3/4 of a cubic metre per hour.

The tower is painted in bands 1 metre broad, alte nately red and black; iron steps lead to an upper gallery, al of iron, and which can serve as a refuge in case of wrec

The works were not contracted for. The cost amount to 92 000 francs and is divided as follows:

Installation, personnel, purchase of material, and sundry expenses	7 876f,97
Foundation	43 075,07
Cast-iron tubes and galvanized bars	2 659,60
Boring of holes	23 336,36
Tower above the water	15 022,00
	92 000f,00

The plan was prepared and the works executed by M. Koziorowicz, engineer, under the direction of MM. Celler, engineer in chief, for the plan, and Gay, engineer in chief, for the construction. The « conducteurs » who assisted the engineers in the superintendence were MM. Giraud, for the foundations, and Ilari, for the boring of the holes and the construction of the tower. The cement was supplied by the house of Désiré Michel, of Marseille.

XXI

PLANIER LIGHTHOUSE.

(DEPARTMENT OF THE BOUCHES-DU-RHÔNE.)

At a distance of 8 miles S. E. of the entrance to the port of Marseilles, is a vast mass of rocks for the most part under water, and which emerge at one point only, where they form the islet of Planier, which is 200 metres in length from E. to W. and 100 metres in breadth. It consists only of rocks and has a flat surface, the most elevated point of which is only $4^{m},50$ above flood-tide; in the heavy swells from S. E. to South and West, the waves cover the isle even to the approaches of the lighthouse tower.

The sides of the isle are perpendicular, but several little creeks exist where it is possible to land, when the weather is favourable, care being taken to select one to leeward. They are however very small, and have not more than 1 or 2 metres of water, owing to which circumstance only boats of small dimensions can enter them.

The rock which constitutes the islet of Planier, is a compact limestone of a light brown colour, and is quite bare throughout the island, but in consequence of the dislocations they have suffered, the surface beds are uneven and fractured, and do not offer a base of the solidity requisite for a structure of importance.

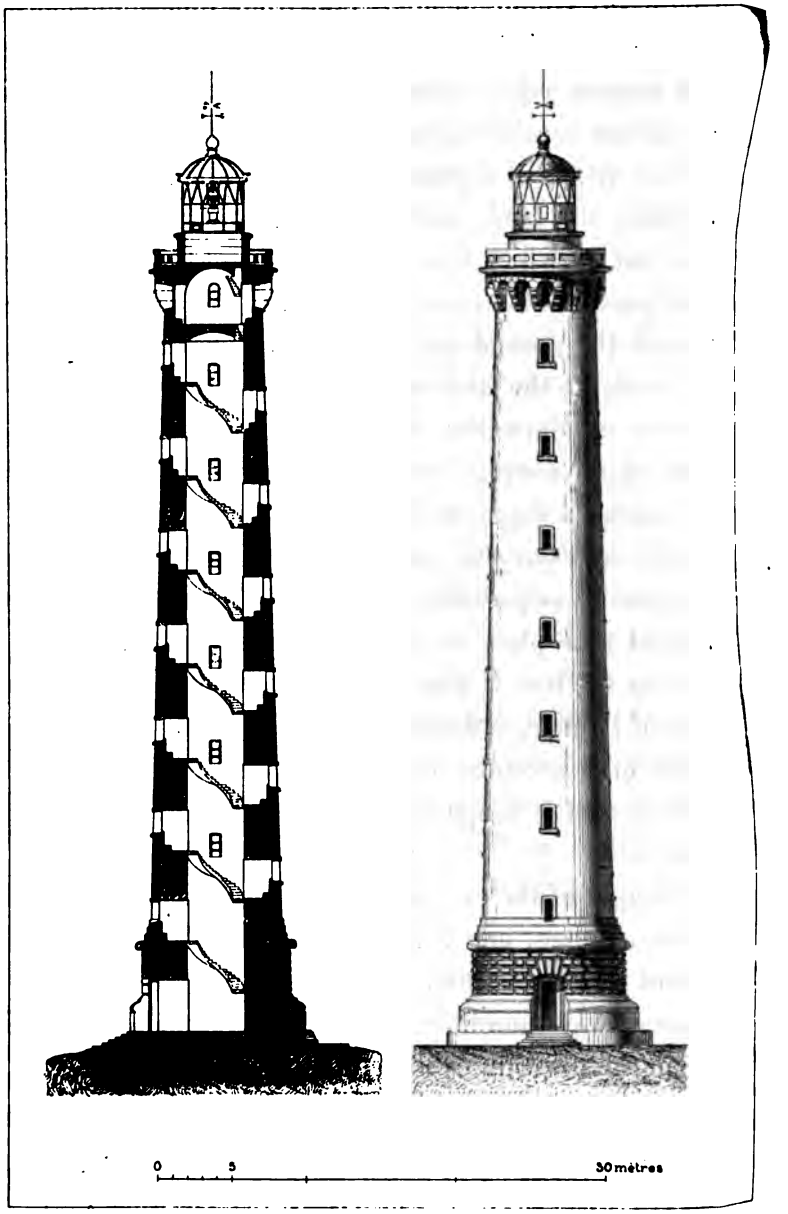
Being situated at the entrance of the bay of Marseilles, it

'ill be easily comprehended, that from time immemorial ıis islet has been pointed out to navigators, and an old tower n the eastern side originally served for this purpose. In 829, it was considered necessary to establish at Planier a ghthouse visible at a great distance, for the benefit of ves- ɛls making the land, and on the West side a tower was ɔnstructed, on which was placed a light of the First Order, ith eclipses at intervals of 30 seconds, and a focus 36 me- ɾes above the ground and 40 metres above flood-tides.

But owing to the immense development of the maritime ɔommerce of Marseilles, and especially since the period hat the employment of steam became general, the speed of vessels has been augmented to such a degree that it was imperatively necessary to render the approaches of the port as conspicuous as possible, so that neither error nor hesitation might take place on the part of vessels at a long distance from the isle. It was therefore decided to establish on the isle of Planier, a flashing electric light with eclipses at intervals of 5 seconds, and a red flash succeeding three white flashes, the range of which would be about 23 nautical miles.

The height of the existing tower was not sufficient for so extensive a range, and the nature of the construction did not admit of any addition to its height; the erection of a new tower was therefore resolved upon, and this work is shown in the drawing exhibited.

It is cylindrical in form, and is built in rubble masonry, pugged with mortar made of hydraulic lime from Theil and fresh sand from the isle of Riou. Ashlar is only used for the revetment of the base. and for the cornice and parapet


0
5
30 mètres

f the crown; the facing of the shaft is composed of a layer f Portland cement. The stair is in ashlar, but the casing ı simply faced with a layer of Valentine cement. The rubble ras obtained partly on the isle itself, and partly on the ıainland from the Catalan quarries; the ashlar came from eds called « plombés », in the Cassis quarries.

The base rests on a foundation platform, levelled to ^{m},33 above high water. The height of the base above this ılatform is $8^{m},60$, of the shaft $42^{m},44$ and of the crown ^{m},45; the focus will be $55^{m},60$ above the foundation ılatform and consequently $6^{m},93$ above flood-tides.

The radii of the horizontal circular sections of the tower ıre as follows; $3^{m},35$ at the top of the shaft, $4^{m},40$ at the base of the shaft and $6^{m},90$ at the bottom of the surbase-ment. The interior space forming the staircase is a cylinder 4 metres in diameter.

The keepers are not lodged in the tower, neither is there ıny store room in it. These necessary dependencies are ound in the buildings which previously served for that pur-ıose.

The plan was prepared by M. Bernard, engineer in chief, ınd by M. André, engineer, from the designs and indications ıf M. Léonce Reynaud, Director of the Lighthouse and Bea-on Service.

The works are executed under the direction of M. Ber-ıard, engineer in chief; they were commenced by M. André, ngineer, and are continued by M. Sebillotte, principal « conducteur » doing duty as engineer; they are superin-tended by M. Levens, principal « conducteur ».

The new lighthouse of Planier is to be lighted by elec-

tricity, and it is anticipated that the light will appear by the end of the present season.

In one of the following notices, some information is given respecting the optical apparatus.

XXII

ELECTRIC LIGHT APPARATUS

FOR LIGHTHOUSES.

The application of the electric light to lighthouses, dates as far back as the year 1864, or sixteen years, but the system has not spread as rapidly as might have been expected. At the present time there are only three lighthouses in France, that are furnished with the electric light; two at Cape La Hève and one at Cape Gris-Nez, and this fact is not difficult to understand. It does not arise from the defective character of the apparatus for generating the electric currents, or for converting them into light, or that accidents have occurred; on the contrary, it must be admitted that their manner of working has been in all respects eminently satisfactory. But the principal lighthouses on the coasts of France have long been provided with optical apparatus made expressly to be illuminated by oil lights, and it follows, not only that the capital thus represented would of necessity be sacrificed, but that the adoption of the new system would entail the expenditure of a sum equally important, and this fact sufficiently explains the reason why the employment of electricity has been deferred.

It is however to be remarked, that the lenticular apparatus, established during the first few years after the invention of Fresnel, have deteriorated to an extent which interferes considerably with their power of effectively concentrating

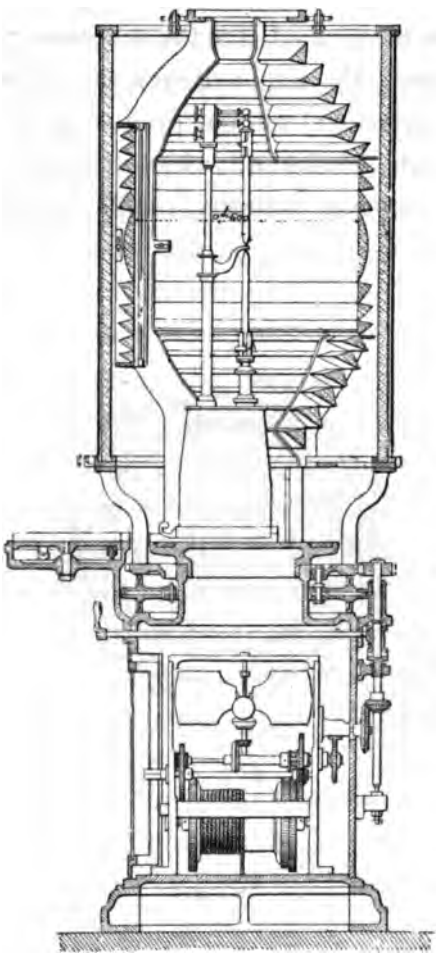
the light; the mirrors which, in these apparatus, take the place of the catadioptric rings now employed, are everywhere more or less damaged, and the lenses are of polygonal shapes inferior to the circular form long since adopted In proportion therefore to the necessity of renewing the old apparatus, will arise the question of the advantage to be gained by the substitution of the electric light, local circumstances being taken into consideration.

This problem has already presented itself in the case of the Planier lighthouse, the tower of which is in course of reconstruction, and the old apparatus for lighting has been condemned as being no longer fit for service. Taking in consideration the importance of the harbour of Marseilles, it was decided that the new lighthouse should be illuminated by means of electricity.

In the establishment of the Hève and Gris-Nez lighthouses, some difficulty was experienced in endeavouring to preserve the character of those lighted with oil; the light of the Hève are fixed, while that of Gris-Nez show 30 eclipses in 30 seconds. But for the Planier lighthouse which was of the latter description, it was considered important to adopt a character more distinctive and better fitted to avoid confusion with the neighbouring lights, and it was consequently decided that the new light should show flashes at intervals of 5 seconds, three white flashes and one red.

The optical system by which this new character of light is produced, is represented by the drawings now shown at the Exhibition. It consists of an apparatus with an interior diameter of $0^{m},60$, and a movable cylinder of ver-

tical lenses, of which the plan and elevation are given in the annexed figures. Notwithstanding the disadvantage of-

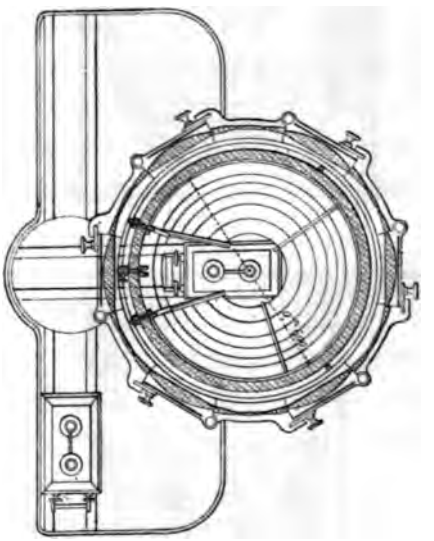


Vertical section.

Scale of $0^{m},05$ to 1 metre.

fered by the passage of the light through two succeding lenses, this combination was deemed preferable to the em-

ployment of annular lenses. The divergence of the tric light being insufficient to ensure the duration ess for the flashes, the calculations for the apparatus mu made with a view to augment it in the necessary propo With annular lenses, this augmentation cannot be obt in a horizontal direction, without producing it simul ously in a vertical direction, which entails a ser diminution of luminous intensity, while by the sy



Plan.

Scale of $0^{m},95$ to 1 metre.

adopted, the necessary duration is given to the flashe augmenting the horizontal divergence of the lenses o cylinder, without any alteration in the vertical diverg of the fixed light apparatus.

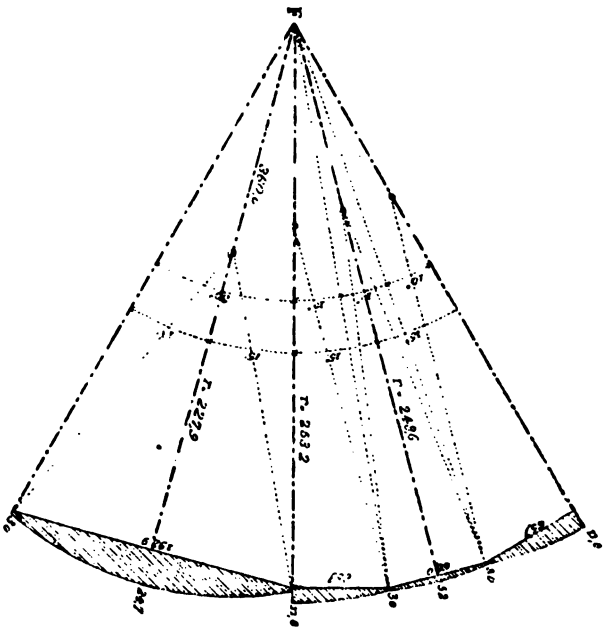
The movable cylinder comprises six panels of four le

one red and three white; one of the panels is represented below.

The lenses for producing the red flashes embrace 30 degrees, while those that show the white only occupy 10. Special experiments have clearly demonstrated that the proportion of intensities ought at least to be equal to 3, in order to give, with the red glass adopted for this apparatus, the same range to the red flashes as to the white. To preserve equal intervals between the flashes, notwithstanding the inequality in the breadth of the lenses, the white lenses next to the red, have been reduced to half lenses, having their optical centre on the extreme edge; the axis is thus 15 degrees from that of the red lens, and 15 degrees from that of the white, so that when the apparatus makes a revolution in 120 seconds, the twenty-four flashes succeed each other at equal intervals of 5 seconds.

The apparatus being intended to illuminate the whole horizon, it became necessary to consider and adopt the best arrangements for the ingress and egress of the lamp. Two lines of rails at a sharp angle, would have required doors of too large a size, consequently a single line has been adopted, ending in a turn-table outside the apparatus, and communicating with another line of rails perpendicular to the first; thus one lamp can be substituted for the other with the same facility as in the case of an open or free angle, and the only inconvenience attending this operation, is the necessity of stopping the rotation of the cylinder for a few instants, in order to open the two doors. When the lamp is in position, the handles for regulating the distance of the carbon points, and for bringing them to the focal plane, are

under the optical apparatus and within reach of the keeper, who by standing on a stool, can reach the handles of the upper part of the lamp, that serve for the adjustment of the carbon points, but which ordinarily are only required to be touched at the moment of putting the carbon points in place. For the purpose of verifying from the exterior the



Horizontal section of one sixth of the movable cylinder.

Scale of $0^{m},20$ to 1 metre.

height and distance apart of the carbon points, a rectangular prism was fixed in the armature of the light; the faces of the prism forming the right angle, are spherical, with a curve calculated to throw an enlarged image of the carbon points upon the service table. The keeper can observe,

ıis image and with his hand upon the regulating handles e can at the same time correct any variation of the lumi-ɔus focus.

The lenses of the cylinder are calculated so as to give a ɔrizontal divergence of 3 degrees, and consequently a du-ıtion of 1 second for each flash. The fixed light apparatus ves an intensity equal to about fifty times that of the elec-ic light placed in the focus; the vertical white lenses nearly uadruple this intensity, so that the flashes are equal to two undred times the focal light; supposing for example a light f 500 Carcel burners, then each flash would be equal to 00 000 burners. The lenses for producing the red flashes ive an intensity three times greater, but when the colour taken into consideration, the flashes produced have nearly ıe same range as the white flashes.

This optical apparatus was made by MM. L. Sautter, ıemonnier and C°, lighthouse constructors, Paris.

The electric regulator in which the light will be produced, as invented and made by M. V. Serrin.

The electric current will be obtained by means of ma-ıeto-electric apparatus of the Alliance Company, perfected ıd constructed by M. Joseph Van Malderen; this apparatus ɔnsists of two machines with five discs arranged to work gether or separately.

The plans of the lighting apparatus described in this no-ce were prepared under the direction of M. Léonce Rey-ıud, Inspector general, by M. Émile Allard, engineer in hief « des Ponts et Chaussées », assisted by M. Dénéchaux, ɔrincipal « conducteur » doing duty as engineer.

XXIII

APPARATUS OF THE SECOND ORDER,

PILIER LIGHTHOUSE.

NEW PROFILE.

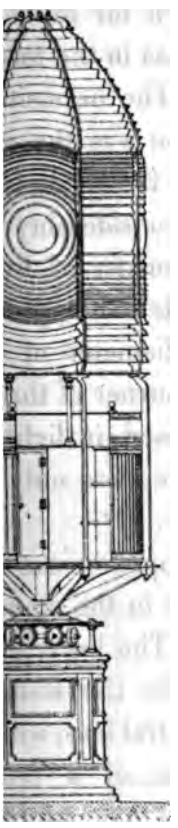
Drawings on a scale of $0^{m},20$ to a metre ($\frac{1}{5}$).

In 1878, this apparatus was placed at the top a towe built on the islet of Pilier, at the embouchure of the Loire and intended to replace the old lighthouse which was in ba condition. The figures following show the plan and eleva tion of the apparatus, also the section of one of the lense

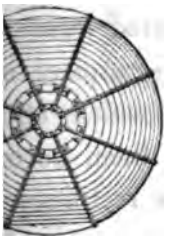
The character assigned to this lighthouse was that of fixed light varied by flashes, and a fixed light apparatus wa adopted, of which two sectors with 1/8 of horizon, an opposite to each other, are replaced by panels of annula lenses, and this apparatus revolves at the rate of one revo lution in 8 minutes. In order that the two orders of lense may join at the edges and that one toothed rack may serv for both, the focal distance, which is $0^{m},700$ for the lense of the fixed light, was reduced to $0^{m},647$ for the annula lenses.

The section of these lenses presents some new dispositions In the central or dioptric parts, the joints separating th elements, instead of being horizontal, incline in the directio

efracted ray. This system possesses several advantages. It dispenses with a triangular part of glass which is useless, and consequently diminishes the weight of the apparatus; it considerably reduces the loss of light caused by the horizontal joints; it renders the exterior angles of the elements less sharp, and consequently less fragile, and in addition it diminishes their projection which allows a greater height to be given to the dioptric lens. In effect, this lens embraces a vertical angle of 76 degrees, while in the former sections, it only occupied about 60 degrees; the height is therefore increased from $0^m,85$ to $1^m,10$ This arrangement accomplishes the condition that the luminous rays should meet the last dioptric element in the same angle as the first catadioptric ring, and should suffer on both the same loss by reflection.



Elevation.



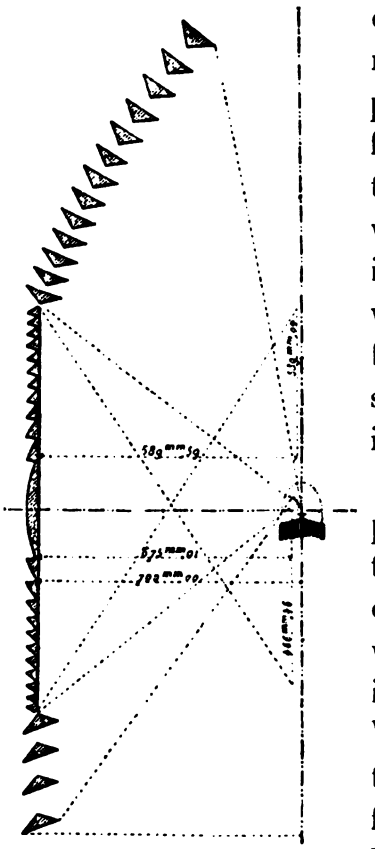
Plan.

of $0^m,02$ to 1 metre.

The method of calculation for the lower elements of the dioptric lens and for the lower catadioptric rings, was in some degree modified. For these different elements, it was necessary to determine the real form of

tion of flame that the base of the burner allows to

be visible from each, and a point, near the centre of gr vity of this portion of flame was taken for focus, inste of placing it in the centre of the lamp, as in the former ca culations. The necessity of th modification was the more ap parent, as the diameter of th flame was considerably augmen ted; the burner of five wick which lights the apparatus ha in fact a diameter of $0^m,110$ while the burner of three wick formerly used in lights of th second order was only $0^m,07$ in diameter.

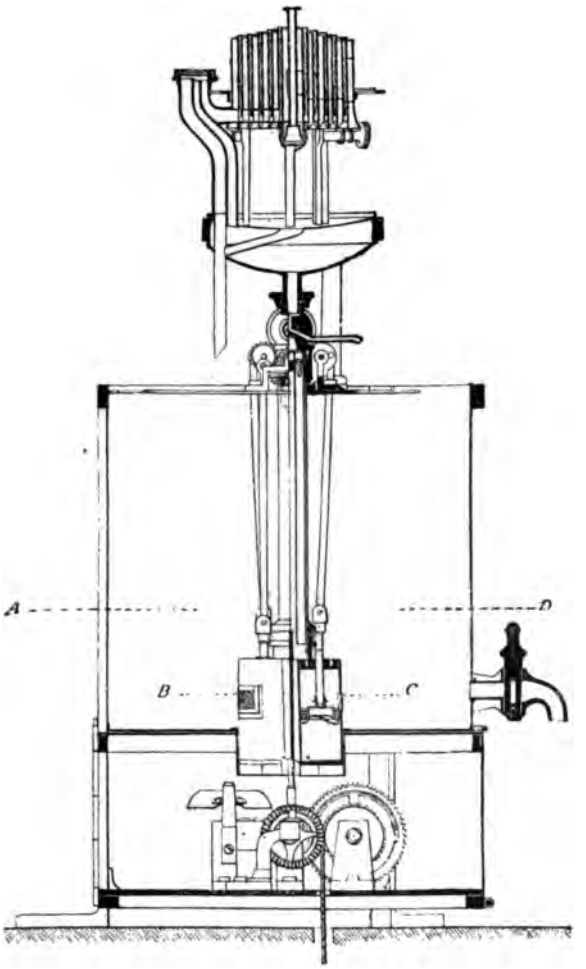


Section of the fixed light lenses.
Scale of $0^m,05$ to 1 metre.

Some improvement may l pointed out in the mounting the lenses. The lower rings a contained in the some fram with the central lens, without th interposition of a crosspiec With respect to the higher ring they are mounted in a seco frame separated from the fi by a metal crosspiece of a c cular form which allows t rings to remain intact instead of cutting them horizontal as was done formerly in order to fix a rectilinear cro piece.

The lamp represented in the two figures annexed, pr sents some peculiar arrangements contrived by M. Dén

CHAUX, doing duty as engineer in the Central Lighthouse Service. Thus the skin valves and the leather clack-valves,



Vertical section of the burner.

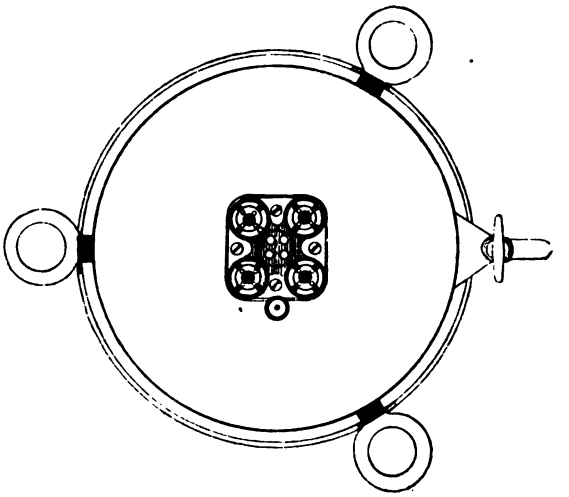
Scale of $\frac{2}{15}$.

being liable to get out of order, were replaced by ordinary pistons and metal clack-valves. In addition to this, as the

body of the pump is immersed in the oil, it was possible to make the reservoir much larger without augmenting the external dimensions of the lamp.

The burner of this lamp consists of five concentric wicks arranged in steps, each wick being $0^m,002$ below the preceding one, starting from the centre. The object of this disposition is to lower, as much as possible, the edge of the burner in relation to the centre of the flame, and thus to diminish the occultation produced of the lower parts of the lens.

The intensity obtained by burning mineral oil in this



Plan of the burner.

Scale of $\frac{2}{15}$.

lamp of five wicks, is equal to 36 Carcel burners, and the entire annular panel gives a flash of more than 5 000 bur-

This apparatus was constructed by MM. HENRY-LEPAUTE ıd Son, lighthouse constructors, Paris.

The plans and specifications were prepared under the rection of M. Léonce REYNAUD, Inspector general, by . Émile ALLARD, engineer in chief « des Ponts et Chaus- es », assisted by M. DÉNÉCHAUX, principal « conducteur » :ting as engineer.

XXIV

APPARATUS FOR TIDE SIGNALS

DURING THE NIGHT.

Drawings on a scale of $0^m,20$ to a metre ($\frac{1}{5}$).

The tide signals, for apprising mariners of the different heights of the water in a port or channel, are made during the day by means of balloons hoisted on a mast on a yard. The signal only commence when the height exceeds 2 metres, a balloon placed at the intersection of the mast and the yard, as also every balloon placed below this one, indicates an addition of 1 metre to the primitive height of 2 metres, and every one placed above, adds 2 metres. The fractions of a metre are signalled by balloons hoisted at either extremity of the yard; when the balloon appears on the left of the mast, it indicates $0^m,25$; when it is seen on the right, it means $0^m,50$; the two together show $0^m,75$.

These indications for signalling the state of the tide are completed by a white flag with a black cross and a black pendant in form a guidon or steamer.

Previously to 1876, the height of the tide was not given during the night. But in consequence of the representation of the pilots of the lower Seine, and the increased development of navigation on the Seine during the last few years, it was decided to establish an apparatus in the port of Honfleur in order furnish the pilots with indications of the

eight of the tide during the night, which were given by he signal mast during the day.

To accomplish this object, it was sufficient to produce a eries of flashes, the number of which could be varied at iscretion, and give to some of these flashes a colour which hould represent the number of metres, and to others a dif- erent colour showing the quarters of a metre, while the ignal thus produced would be separated from the succe- ing one by a fixed light. The drawing exhibited represents n apparatus which carries out this combination.

It consists of a fixed light $0^m,50$ in diameter, lighting half he horizon; of a catadioptric reflector occupying the other alf, and of a half cylinder with eight vertical lenses, each mbracing 22 1/2 degrees. Five of these lenses are coloured reen, and three red; they are also arranged in such a anner as to be put in or taken out of position, as may be equired; or rather, to avoid displacements they can turn n a vertical axis so as to place themselves in a diametral lane of the apparatus, and in this position they only affect ie fixed light by causing a slight occultation, and this is lmost imperceptible when a lamp of two wicks employed. hese lenses are held in the position they are to take, by pring catches. The rotation is effected in 80 seconds and an be accelerated on occasion. The apparatus moves so as o show the red lenses before the green.

The following details explain the method working this pparatus. Similarly to all tide lights, it is lighted as soon s the tide attains a height of 2 metres above the lowest bb; all the lenses are taken out or placed in the diametral lanes, so that the appearance of a fixed light is presented.

When the water reaches $2^m,25$ the keeper puts in position a green lens, which is the first in the direction of the movement; then a green flash is preceded and followed by a short eclipse every 80 seconds, after which is shown a fixed white light, lasting 75 seconds between each flash. When the water attains $2^m,50$ a second green lens put in position and a third at 2^m, 75. At this period, two and then three green flashes succeed each other at intervals of 5 seconds, followed by a fixed white light during 70 or 65 seconds and repeated every 80 seconds. At 3 metres of water the keeper removes or turns the three green lenses, and puts in position the last red lens in the direction of the movement viz. in that of the first green lens. The red lens adds a metre to the primitive height of 2 metres, and thus represents 3 metres of water. By replacing successively the first, second and third of the green lenses immediately following the red, the tide is signalled to be $3^m,25$, $3^m,50$ and $3^m,75$ respectively. For 4 metres the three green lenses are again turned and the second red lens is put in position, so that two red flashes are shown indicating an addition of 2 metres to the primitive height, and consequently representing 4 metres. Continuing in this manner, five red and three green flashes can be produced, succeeding each other at intervals of 5 seconds and followed by a fixed white light lasting 40 seconds. This signal indicates a height of $7^m,75$ which exceeds ordinary requirements. When the tide is ebbing, the same signals are made in an inverse order, and the light is extinguished as soon as the water has fallen to 2 metres.

In this apparatus the fixed white light possesses an inten-

sity of 81 burners and a range of 13 miles 1/2; the intensity of the flashes is equal to about 250 burners of white light; the range is 12 miles for the red and may be supposed to be nearly the same for the green, allowing for a little lightness of colour, which in this case is not attended with any disadvantage.

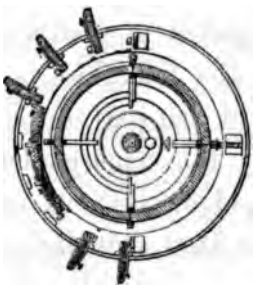
The flashes are produced by means of lenses coloured in their whole thickness. This method of colouring was first applied in 1876, to the tide signal apparatus in the port of Honfleur, and is represented in plan and elevation by the four figures annexed.

The system just described is completed in such a manner as to indicate the progress of the tide. Two opaque screens are placed near the middle of that part of the movable cylinder that does not carry the coloured lenses, and these screens produce two rapid occultations nearly in the middle of the duration of the fixed white light. The screens are removable and can produce 3 signals, viz. two occultations, if they are left in position; one if one screen is removed, and no occultation, if both are removed. It is understood that one occultation indicates that the tide is rising, and two show that it is falling, while the absence of any occultation signifies slack water. When the water is lower than 2 metres, the fixed light is coloured red if the tide is rising, and green if it is falling. The fixed light appears white, only when the water is at the height of 2 metres or more.

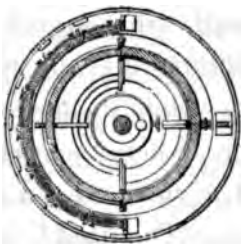
The apparatus comprising these indications and which is represented by the drawings shown at the Exhibition, has been in operation at Dunkirk since 1878.

The plans of the apparatus were drawn, under the direction of M. Léonce Reynaud, Inspector general, by M. Émile Allard, engineer in chief « des Ponts et chaussées », assisted by M. Dénéchaux, principal « conducteur » acting as engineer.

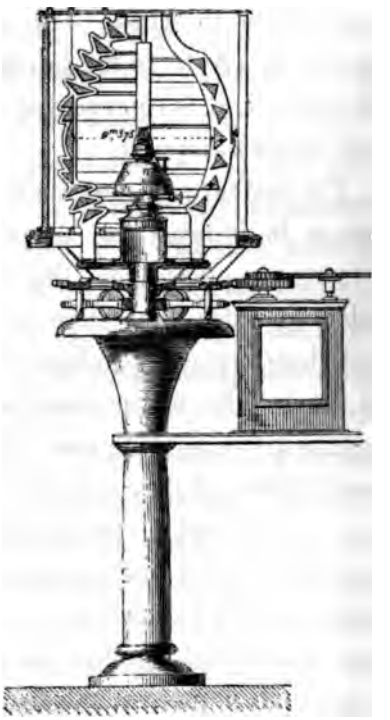
Signal for 2 metres.



Signal for 4m,25.



Signal for 7m,75.



Vertical Section.

Scale of 0m,05 for 1 metre.

XXV

REPORT ON THE LIGHTS AND BEACONS

ON THE COASTS OF FRANCE.

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1 volume of text in-4° to and an atlas in-folio.

Report on the lights and beacons on the coasts of France by M. Léonce Reybaud, Inspector general « des Ponts et Chaussées », Director of the Lighthouse and Beacon Service etc., published by order of the Minister of Agriculture, Commerce, and Public Works. Paris, National Press, 1864.

XXVI

REPORT ON THE INTENSITY AND RANGE OF LIGHTS.

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1 volume in-4° to with plates.

Report on the intensity and range of lights, comprising a description of some new apparatus, studies on the transparence of flames, the visibility of flashing lights, and the nocturnal transparence of the atmosphere, by M. E. Allard engineer in chief « des Ponts et Chaussées », attached to the Central Lighthouse Service; published by order of the Minister of Public Works. Paris, National Press, 1876.

XXVII

STATE OF THE LIGHTS AND BEACONS

ON THE COAST OF FRANCE.

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1 volume in large 8° vo with map.

This volume was compiled up to the date of the 1st January 1876, but it is completed up to the 1st July 1877 by means of a corrected report. It contains a map of the lighthouses on the French coasts up to the 1st January 1876.

These lighthouses may be divided into seven principal systems, according to their distinctive characters : fixed lights; lights with eclipses; fixed lights varied by flashes; flashing lights; lights alternately fixed and flashing; twinkling lights and variously coloured lights. They are divided into five orders according to the diameter of the optical apparatus that light them. This diameter is $1^m,84$ for the First Order; $1^m,40$ for the Second; 1 metre for the Third; $0^m,50$ for the Fourth and $0^m,375$ or less for the Fifth.

The range of the lights varies in long distances according to the transparency of the atmosphere. The calculations given in the lighthouse book were made by M. Allard, engineer in chief, and are based upon an average degree of transparency.

This degree is such, that the transparency of the atmosphere is superior to it during half the time, and remains

below it during the other half; it was determined by mea
of observations made and registered by the lighthouse ke
pers, on the visibility of the neighbouring lights; this w
done three times a night. It follows from this definition th
the number given as representing the range of a lighthous
has but a relative value; for instance, when 21 miles are give
as designating the range of a fixed sea light of the First O
der, it means that at that distance it will be visible half t
time and invisible during the other half, or in other wor
the probability of perceiving it will be equal to 1/2. But
can be seen much farther, or it will only be visible at a mu
shorter distance: thus for example, at 39 miles it will
visible 1/12 of the time, at 33 miles 2/12 and so fort
that is to say that at these different distances the probab
ities of perceiving the light will be respectively equal
1/12, 2/12, etc.; while on the other hand, at a distance
8 miles it will be visible for 11/12 of the time and will or
disappear during the other 1/12; at 12 miles, it will be v
ible during 10/12 of the time; in other words, the prob
bilities of seeing the light at these different distances a
respectively 11/12, 10/12, etc.

The geographical range of each light is indicated by t
side of the luminous range, that is to say the distance
which it is visible in proportion to its level above the s
The curvature of the sea and the average atmospheric
fraction are taken into consideration in calculating t
range.

Works relating to beacons comprise stone towers, be
cons, buoys, landmarks.

A uniform system of colouring is observed for all buo

and beacons. Those that mariners should leave to starboard in coming from the open sea, are painted red; those to be left to the larboard, are painted black, while those that may be left on either side, indiscriminately, are painted in horizontal bands of red and black alternately. The work on the state of the beacons shows these different colourings.

XXVIII

COMMEMORATIVE MEDAL.

The object of this medal is to perpetuate the brance of the services rendered by France to estal of maritime lights and beacons.

The face represents France standing on the sea the night, and calm in the midst of the tempes hand she holds a beacon light; in the other an o fog trumpet. The inscription is as follows,

GALLIA PRÆLVCENTE
TVTA NAVTIS LITTORA.

It was composed by the « Académie des Inscri Belles-Lettres. »

The reverse represents a view of the sea, with types of lighthouses, beacons and buoys, and un in the exergue, is the following inscription :

1791. LIGHTS WITH PARABOLIC REFLECTORS, TEULÈRE AND BOI
1823. LENTICULAR LIGHTS. AUGUSTIN FRESNEL.
1864. LIGHTING THE LIGHTHOUSES OF LA HÈVE BY THE ELECTRIC I
1875. LIGHTING BY PETROLEUM.
1878. THE COASTS OF FRANCE ARE DISTINGUISHED BY,
372 LIGHTHOUSES, 760 BUOYS AND 1450 BEACONS.

This medal was executed by M. DEGEORGE.

GALLIA PRAECINCTE TVTA NAVTIS LITTORA

MINISTÈRE DES TRAVAUX PUBLICS. PHARES ET BALISES.
1791 PHARES À RÉFLECTEURS PARABOLIQUES TEULÈRE ET BORDA
1823 PHARES LENTICULAIRES AUGUSTIN FRESNEL
1864 ECLAIRAGE ÉLECTRIQUE DES PHARES DE LA HÈVE
1875 ECLAIRAGE DES PHARES À L'HUILE MINÉRALE
1878 LES CÔTES DE FRANCE SONT SIGNALÉES
PAR 372 PHARES 760 BOUÉES
ET 1450 BALISES.

SIXTH SECTION.

RAILWAYS.

XXIX

POMPADOUR VIADUCT,

ON THE BOUCHAT TORRENT.

LIMOGES AND BRIVES LINE.

(ORLÉANS RAILWAY COMPAGNY.)

Model of four arches on a scale of $0^m,04$ to metre.

Site and general arrangements. — The Pompadour viaduct is situated on the line of railway from Limoges to Brives, 7 kilometres after the Pompadour station and 2 500 metres before arriving at that of Vignols-Saint-Solve. It consist of eight arches of 25 metres span and has a total length of 285 metres. The height is 55 metres above the lowest point of the valley.

Foundations. — The viaduct is founded on mica-schist, the rock being extremely hard and solid; it is however dislocated by a granitic upheaval which crops up at a distance of 2 kilometres, above the town of Vignols. The beds are almost perpendicular, and blasting was frequently necessary to level the rock or to get rid of blocks of precarious solidity.

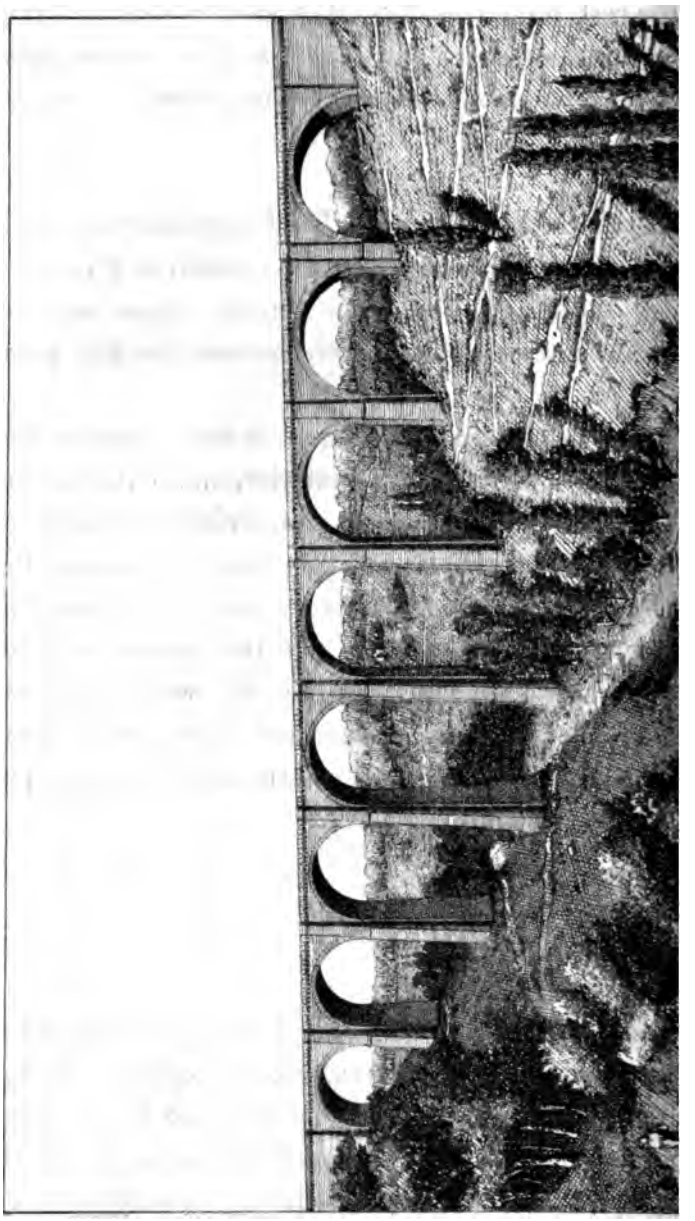
For the rest, no serious difficulty presented itself in laying e foundations of this great work, and the bottom upon hich they rest presents every condition necessary to per- ct solidity.

Mode of construction. — The Pompadour viaduct is nstructed for a single line, and the breadth is $4^{m},55$. On ch pier there are turnouts or shunts $1^{m},90$ long by $^{n},30$, which increase the breadth between the pier para- ts to $5^{m},15$.

The piers are $5^{m},20$ in thickness at the springers and esent a batter of $0^{m},01$ for the interior, and $0^{m},03$ for the terior; they are supported by counterforts $2^{m},70$ broad the level of the springers and projecting $1^{m},32$ from the ce of the piers. The counterforts are built with a batter of $^{n},01$ for the interior and $0^{m},07$ for the exterior, and not ly they prevent the overturning of the work, but they crease the horizontal superficies and consequently dimi- ish the pressures. The highest pressures for the piers, per quare centimetre, are as follows.

At the springers	$6^{k},25$
At the base of the pier	8 ,03
At the base of the socle	7 ,64
An the foundation bottom	5 ,94

All the facings are in scappled rubble, with rusticked ossages; and the same materials were employed for the rojecting and entering angles, and the head bands of the rches; but, in order that the outlines might be clearly efined, and the accuracy of the laying ensured, an edg- ng $0^{m},03$ broad was cut from each side of the edges.



The only parts of the work in ashlar work are the plinths, parapets and abacus of the counterforts.

The space between the spandrels is hollowed by two small longitudinal arches of $1^{m},30$ span, access to which is obtained by means of shafts contrived in the thickness of the counterforts.

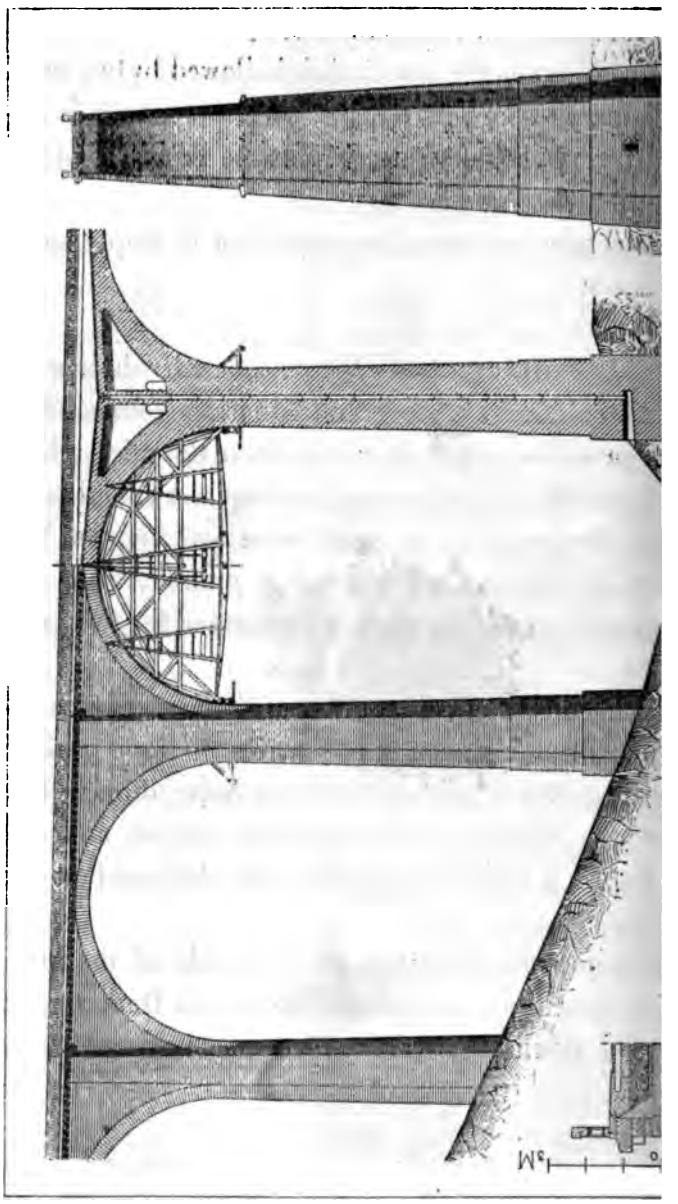
For the whole structure the proportion of empty space to full is 2,08.

Materials employed. — The uncoursed rubble work is done with rubble from the granite quarries commanding Vignols. The upper part is in rubble from the mica-schists found in the valley of the Bouchat near the work, and sandstone from the environs of Saint-Solve and Vignols. The facings are in Peyrolic sandstone; but granite, from the quarries above Vignols, was used at the base of the two great piers.

The lime came from the kilns of Paviers (Indre-et-Loire) and the sand from the quarries of large grained sandstone near the outlet of the Saint-Solve tunnel. This sandstone was crushed and thoroughly washed, and cost not less than 14 francs per metre cube delivered at the work.

In the arches, for 6 metres on each side of the keys, 150 kilogrammes of cement, from the firm of Demarle and Lonquety of Boulogne, were added per cubic metre of mortar.

Difficulties of construction. — Great difficulties were experienced in building the Pompadour viaduct; no road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xisted leading to the site; no quarry was found open, and he high road N° 31 connecting Brives with Vignols was ncapable of bearing the heavy loads of wood and lime required for the works. It was found necessary to remake entirely the roadway of the route N° 31 for a distance of 7 kilometres, and, in addition, to form new roads to obtain access to the viaduct. Many of the quarries opened at the commencement of the work, afforded but indifferent stone, and when, at length, the Peyrolic quarry was discovered, t was found to be 100 metres below the level of the railway, and consequently necessitated the construction of an nclined plane for the conveyance of the materials.

A movable engine of 30 horse-power, was placed at the summit of the inclined plane, and by means of a cable the loaded trucks were drawn up.

The outlay attending these accessory works augmented the cost of construction by 295 000 francs.

Centres. — The centres were supported by iron rails traversing the stone-work of the piers at the level of the springers; each support consisted of two rails weighing 36 kilogrammes par metre run.

For the raising of the centres a frame was employed supported by four wire cables fastened to the rails, and on which three crab-winches were placed.

The time elapsing between the keying of an arch and the striking of its centre may be stated at a maximum of fifty-one day and a minimum of twenty-one.

The settlement of the centres varied from $0^{m},022$ to $0^{m},041$, and after the striking did not exceed 0,07.

The cubic measure of the wood employed for the construction of the centres is 95 metres.

The cost amounted to 9,200 francs per centre.

Time occupied. — The works were commenced without being contracted for in June 1873, and in the season of that year the two great piers were carried up above the second socle while the other piers were only raised a few metres above the bottom. The works were resumed in March 1874 and stopped in November at which period the level of the springers was attained. The masonry of the arches was commenced on the 15th March 1875, the last arch was keyed on the 9th July following, and the structure was entirely completed and opened for traffic in December 1875.

The cost of construction of the Pompadour viaduct may be stated as follows :

DESCRIPTION OF WORK.	COST.	
	TOTALS.	per METRE RUN.
Approaches, search for quarries, road-making	295 000f	1 035f
Foundations.....	50 000	175
Piers and abutments up to springers.....	350 000	1 228
From springers to plinth.....	350 000	1 228
Plinths and parapets.....	65 000	228
Centres.....	90 000	316
TOTAL exclusive of accessory expenses.....	905 000	3 175
TOTAL including accessory expenses.....	1 200 000	4 210

The cost per superficial metre in elevation is :

Exclusive of approaches, quarries and roads, 110 francs;

Including approaches, quarries and roads, 146 francs.

The average cost per cubic metre of the masonry of every description is :

Exclusive of approaches, quarries and roads, 49 francs;

Including approaches, quarries and roads, 65 francs.

The plans were prepared and the works executed under the chief direction of M. DIDION Inspector general « des Ponts et Chaussées », delegate-general of the board of directors of the Orléans Railway Company, and of M. MORANDIÈRE, Inspector general « des Ponts et Chaussées », director of the new works of this company, who was succeeded by M. SÉVÈNE, engineer in chief « des Ponts et Chaussées ».

The engineers who prepared the plans and executed the works are M. DUPUY, engineer in chief « des Ponts et Chaussées », and of the Orléans Railway Company and M. LIÉBEAUX, engineer of the Company.

The exertions of MM. BOURET and MOULINOT, chiefs of the section largely contribued to the satisfactory execution of the works.

And finally the energy and activity displayed by the contractor, M. VARINOT, greatly contributed to the successful completion of contract.

XXX

THE ERDRE VIADUCT,

NANTES AND CHATEAUBRIANT LINE.

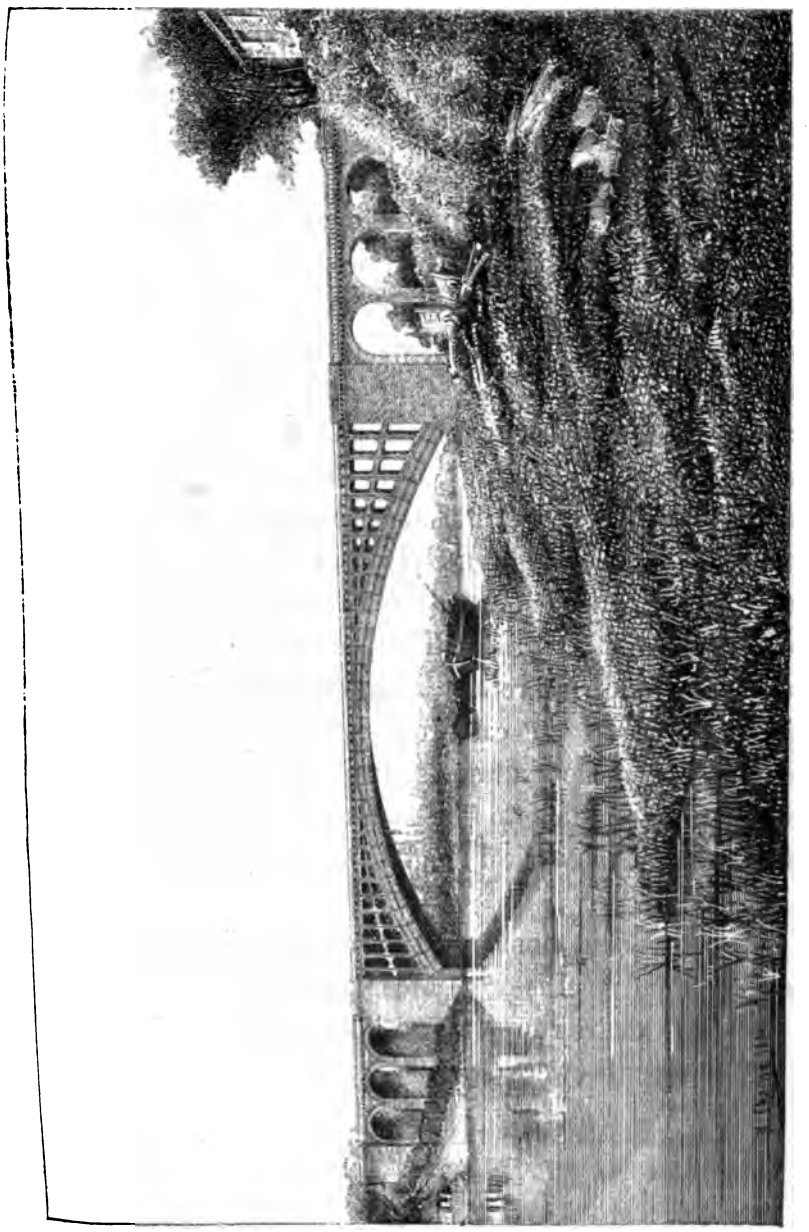
(ORLÉANS RAILWAY COMPANY.)

View of the viaduct and its approaches.

Site and general arrangements. — This viaduct is on the Nantes and Chateaubriant line, 6 miles from the Nantes station.

It was built to cross the river Erdre, which at this point is only 100 metres broad, the bed of the river being confined between two granitic rocks. Along the breath of the river, the bottom is only found at a depth of 20 metres, and the object of the plan adopted was to avoid the construction of intermediate piers, the foundations of which it would have been necessary to lay by means of compressed air.

The work was constructed for a double line, and consists of two parts in masonry connected by an iron arch of 95 metres span, surbased to 1/8. Each part of the masonry is $46^{m},10$ in length and consists of three semicircular arches of 8 metres span and two buttresses $9^{m},35$ in thickness the rails are $18^{m},50$ above low-water mark. The total length of the work is $190^{m},20$ and the breadth 8 metres between the parapets.



Foundations. — The foundation of the left bank abutment was laid at a depth of $7^{m},80$ below low-water mark, and in a water tight enclosure from which the water had been pumped out.

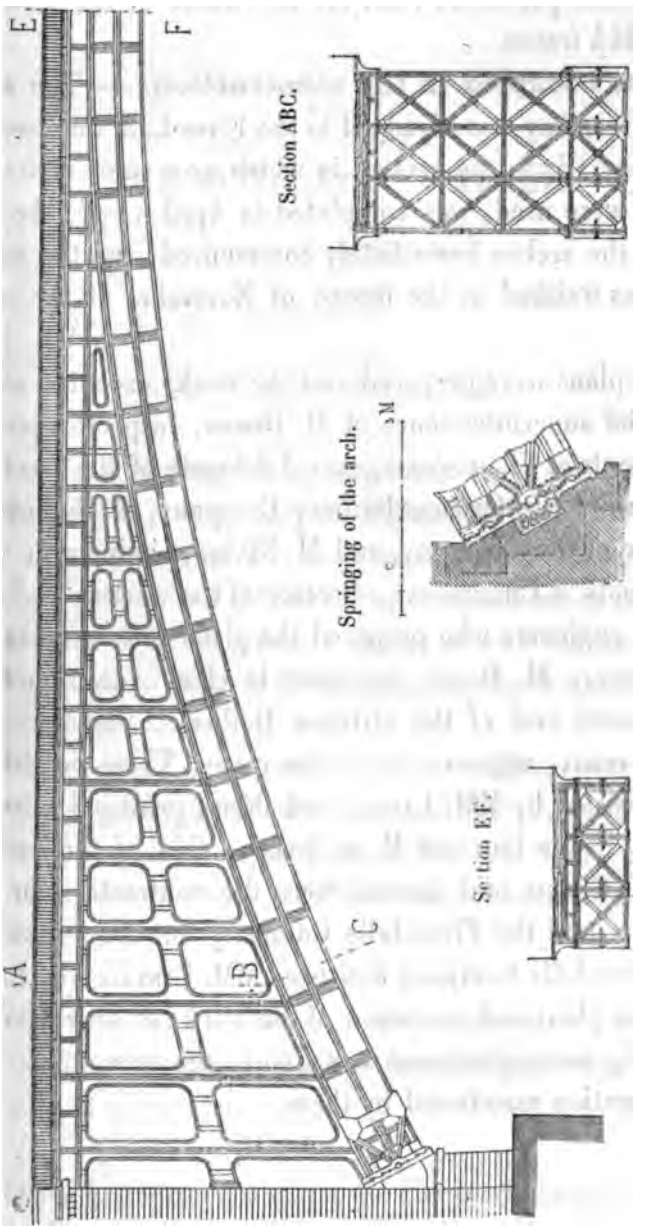
Description of the metallic part. — The great bay is in iron, and consists of four arches $2^{m},20$ apart from axis to axis, with a height of 2^{m}, 20 at the top and $2^{m},50$ at the springers. The span is 95 metres at the lower part, at the rise $12^{m},07$. The upper and lower tables of the arches meet near the abutments and throw back the pressure upon a steel pivot $0^{m},20$ in diameter. The flooring is formed of hammered iron plates riveted to the cross-beams of the bridge and to the string-pieces; a layer of ballast covers the oaken flooring, and the line is laid on the bridge as on other parts of the railway. To counterbalance the effects of expansion, movable rollers, connected with the flooring by joints, slide on the cast-iron supports embedded in the stone-work of the abutments; the slope of the supports is regulated according to the horizontal lengthening of the flooring and the vertical lengthening of the spandrels.

Weight and cost. — The total weight of the metal: cast-iron and steel is 979 000 kilogrammes.

Or, per metre run, 10 000 kilogrammes.

The expenses were:

For two abutments in masonry.....	310 000^{f}
For the iron part.....	520 000
TOTAL.....	830 000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The cost per metre run, for the whole of the viaduct, was 4 364 francs.

Time occupied in the construction. — The work for the iron bay was adjudged to the Fives-Lille Company in February 1876; the centre, in which 700 cubic metres of timber were used, was completed in April 1877, the setting of the arches immediately commenced, and the structure was finished in the month of November of the same year.

The plans were prepared and the works executed under the chief superintendence of M. Didion, Inspector general « des Ponts et Chaussées » general delegate of the board of direction of the Orléans Railway Company, M. Solacroup director of the Company, and M. Sévène, engineer in chief « des Ponts et Chaussées », director of the works.

The engineers who prepared the plans and executed the works were M. Dupuy, engineer in chief « des Ponts et Chaussées » and of the Orléans Railway Company, and M. Geoffroy, engineer of the Company. These gentlemen were assisted by MM. Lauras and Pépin, principal chiefs of sections of the line and M. de Silguy, chief of the section.

MM. Gougis and Leturc were the contractors for the masonry, and the Fives-Lille Company for the iron-work. The Fives-Lille Company entrusted MM. Lantrac and Lhoest with the plans and execution of the work, of which the satisfactory accomplishment was due to the scrupulous care and attention manifested by them.

XXXI

THE VEZOUILLAC VIADUCT.

(RODEZ AND MILLAU LINE.)

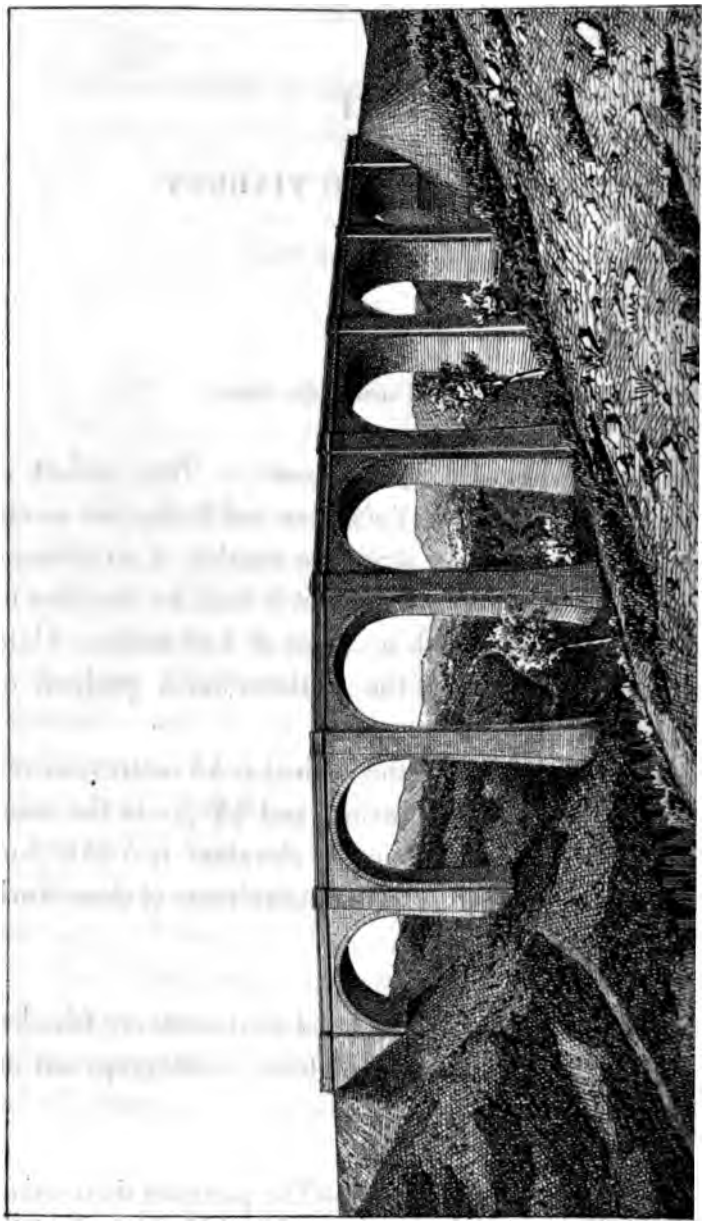
Picture. — Full view of the viaduct.

Site and general dispositions. — This viaduct is situated at the point where the Millau and Rodez line meets the Vezouillac ravine. The structure consists of seven semi-circular arches of 16 metres span; it is built for two lines of rails, and has a curve with a radius of 300 metres, while the longitudinal section of the platform has a gradient of $0^{m},0321$ per metre.

The maximum height of the viaduct is 43 metres, in relation to the bottom of the ravine, and $44^{m},52$ to the foundation bottom. The superficies in elevation is $4445^{m},50$, exclusive of the parapet, and the entire mass of stone-work is 16330 metres.

Foundations. — The piers and abutments are founded upon the argillaceous liassic limestone, which crops out on the sides of the ravine.

Method of construction. — The piers are six in number, and have a trapezoidal section, owing to the curve of the



viaduct. Measured to the springers, their thickness is $3^{m},60$ on the concave head and $4^{m},20$ on the convex.

In order to obtain a uniformity of pressure upon the various courses, the facings were built with a curved batter, and this innovation constitutes the pier a solid of equal resistance, without the necessity of forming offsets at different heights. By the suppression of offsets, the purity of the vertical lines is preserved, and there is nothing to impede the eye from taking in the entire elevation of the structure at a single glance.

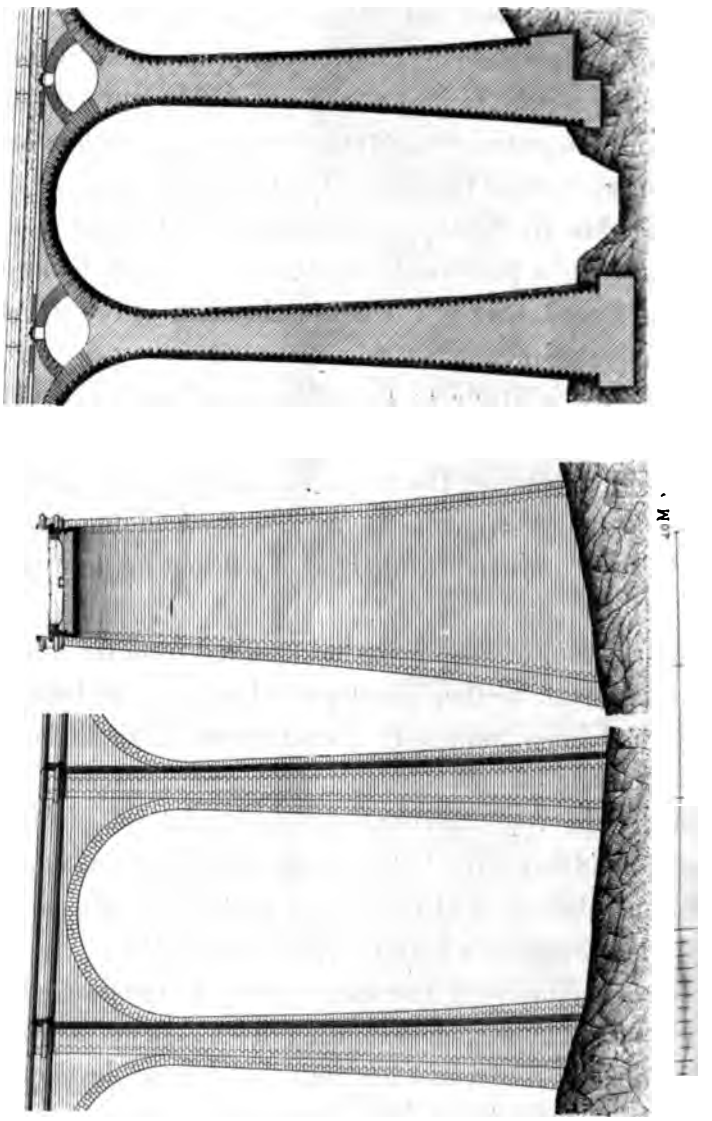
The sole obstacle to the adoption of a curved batter, appeared to be the difficulty of execution, and this was avoided by replacing the continuous curve of the side-faces, by a succession of plane facets described in the theoretic curve, which are substituted for it without being apparent to the eye.

In fact, no inconvenience has resulted from the adoption of this system, neither has it proved more costly than if the piers had been built with a continuous batter throughout their height.

With the view of counteracting the lateral yielding of the piers, the curved batter of the side-faces was augmented, and they were strengthened by the addition of counterforts presenting a batter equally decided.

These counterforts rise continuously to the parapet, and have a greater projection on the convex than on the concave side, in order to resist the centrifugal force developed by the passage of a train along the viaduct.

They conceal, in the lateral faces, the edges of the polygon formed by the arches and the trapeziums of the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ers. They also increase the horizontal superficies of the urses, and thus diminish the pressures by unity of surce.

These pressures had been limited to an average of 6 kilorammes per square centimetre. They may be stated as llows:

At springers	$4^k,99$
At 5 metres below springers	5 ,57
At 10 metres	6 ,03
At 15 metres	6 ,27
At 20 metres	6 ,28
At 25 metres	6 ,17
At 30 metres	5 ,98

The use of squared stone was exclusively confined to the rnice and the blocking-course or coping of the parapets, hich are in ashlar. The archivolts and projecting angles f the piers, the abutments and counterforts, are in coursed bble; the other facings are in scappled rubble.

The springers have no cordon, and it is only in the chivolts that the dressed stone projects beyond the fangs.

In thus dispensing with all appearance of ornament, the rinciple of leaving apparent only the important lines of the ructure was carefully adhered to, and this proceeding ad the satisfactory result of giving to the masonry a chacter of homogeneity specially in accordance with the massive appearance of a great work.

In a viaduct of this height, the vibration caused by the rains must necessarily affect the filling in between the

spandrel walls, and might possibly cause thrusts of a serioi nature, so that to obviate this danger, it was necessary to cor struct a cylindrical relieving arch on the haunches of each the great arches; the axis of this small arch is perpendicul to that of the bridge. This plan was preferred to that of fo ming longitudinal vaults, upon which the combined effect thrusts and centrifugal force was greatly to be feared. Ca was also taken to place the centres of these vaults a litt outside the axes of the piers, and this precaution w adopted with the view of directing towards the centre each pier, the resultant of the vertical forces transmitted the two contiguous semi-cylindrical arches, a resulta which was displaced, owing to the gradient given to t viaduct. Shafts or passages, with man-holes, are contriv along the axis of the platform, and give access to the i terior arches.

Taking into consideration the longitudinal section follow ing the axis of the line, then the proportion of empty t full space in elevation is $1^{m},82$, and the average cube o the masonry per superficial metre in elevation, is $3^{m},67$.

Materials. — The rubble facing is in Verrières sand stone (Aveyron); the rubble used for the interior was lime stone, and was procured from cuttings adjoining the works the sand was taken from the bed of the Tarn; and lastly the hydraulic lime was made from limestone taken from th approaches, and burned in a kiln built for the purpose.

The interior masonry of the piers, in place of being i uncoursed or scappled rubble, as is the case in other grea viaducts, is simply in rough quarry stone. The arches an

Spandrels with convex faces were finished with slowly setting cement mortar.

Centres. — The centres were supported by rails traversing the masonry of the piers at the level of the springers. For each arch, the cube of the wood employed was $1^{m},79$, and the cost of the centre was about 3 000 francs. During the construction, the average settlement of the top was $0^{m},003$, and the settlement of the arches after the striking of the centre $0^{m},004$.

NATURE OF WORK.	COST	
	TOTAL.	per METRE RUN.
Foundations	65 619^{f},00	423^{f},62
Piers and abutments up to springers	235 711 ,64	1 521 ,70
From springers to plinth	290 857 ,82	1 877 ,71
Centres	23 788 ,29	153 ,57
Approaches and accessory works	28 024 ,00	180 ,92
TOTAL above foundations	578 381 ,75	3 733 ,90
TOTAL including foundations	644 000 ,75	4 157 ,53

The cost per superficial metre in elevation, was:

Above the foundations 130^{f},11; including the foundations 144^{f},87.

Finally, the cost per cubic metre of masonry was:

Above the foundations 35^{f},41; including the foundations 39^{f},44.

The viaduct was constructed under the principal direction of M. LEFORT, M. BAUDARD and M. MARX, Inspectors

general « des Ponts et Chaussées ». The engineers that prepared the plans and specifications and directed the works, were M. Robaglia, engineer in chief « des Ponts et Chaussées », and M. Pader, engineer. The working arrangements were superintended by M. Longueville and M. Lamothe, « conducteurs des Ponts et Chaussées ». M. Chêne was the contractor.

XXXII

THE ALTIER VIADUCT,

BRIOUDE AND ALAIS LINE.

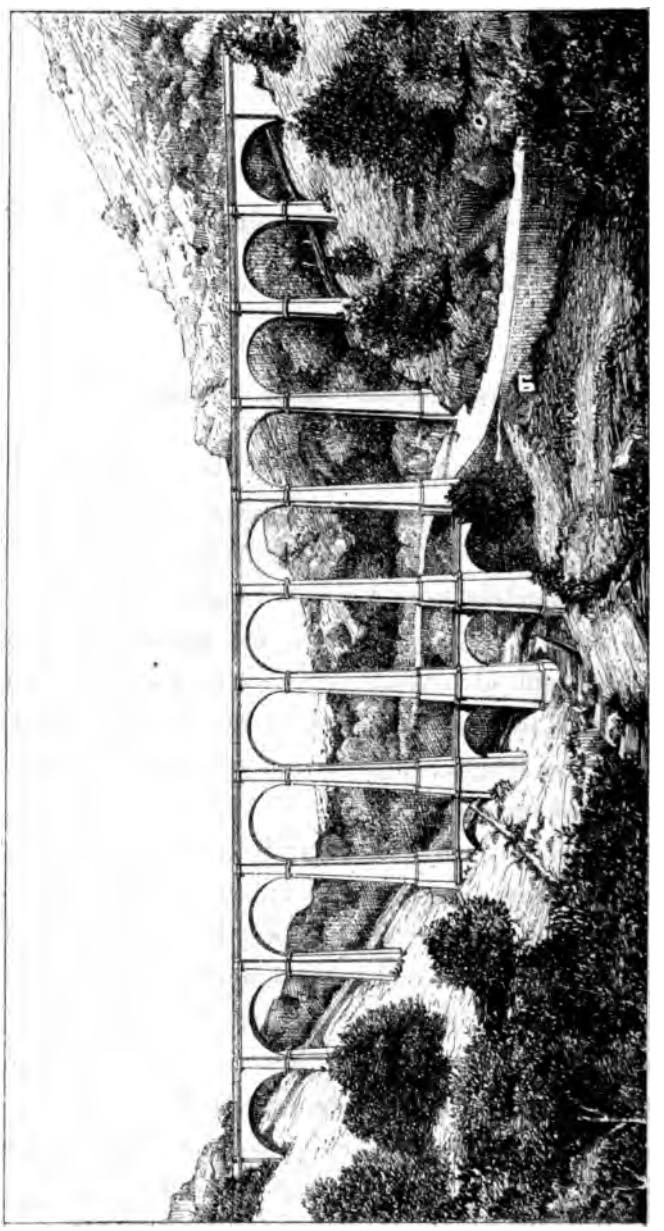
(PARIS, LYONS AND MEDITERRANEAN RAILWAY COMPANY.)

View of the viaduct and its approaches.

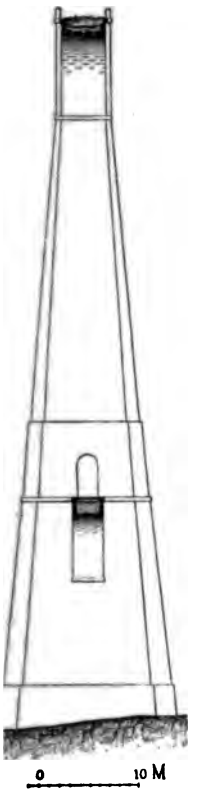
Site and general arrangements. — This viaduct is he most important work on the Brioude and Alais line, and vas built to cross the Altier (a tributary of the Ardèche) at bout 2 kilometres from Villefort (Lozère). In plan it decribes a curve with a radius of 400 metres, and the line as a gradient of $0^{m},025$ per metre. From the foundaion rock to the level of the rails the greatest elevation is $73^{m},33$. The length, measured along the axis of the railay, is 243 metres.

This work is constructed entirely in stone and is intended or a single line. It consists of eleven semicircular arches ith a span of 16 metres; the breadth between the heads $4^{m},50$. The middle and highest piers are connected below y other arches, also semicircular, having a breadth of metres between the heads, above which is a paved banuette or footway $46^{m},85$ below the rails.

Centred passages, 2 metres in span and 4 metres in height nder the key, pass through the piers at the level of this



The piers have a thickness of 4 metres at the springers, and present, between these springers and the crowns of the lower arches, a batter of 3 p. o/o on the lateral faces and of 6 p. o/o on the head faces.



Below the crowns, the batter is respectively, 4 and 7 p. o/o.

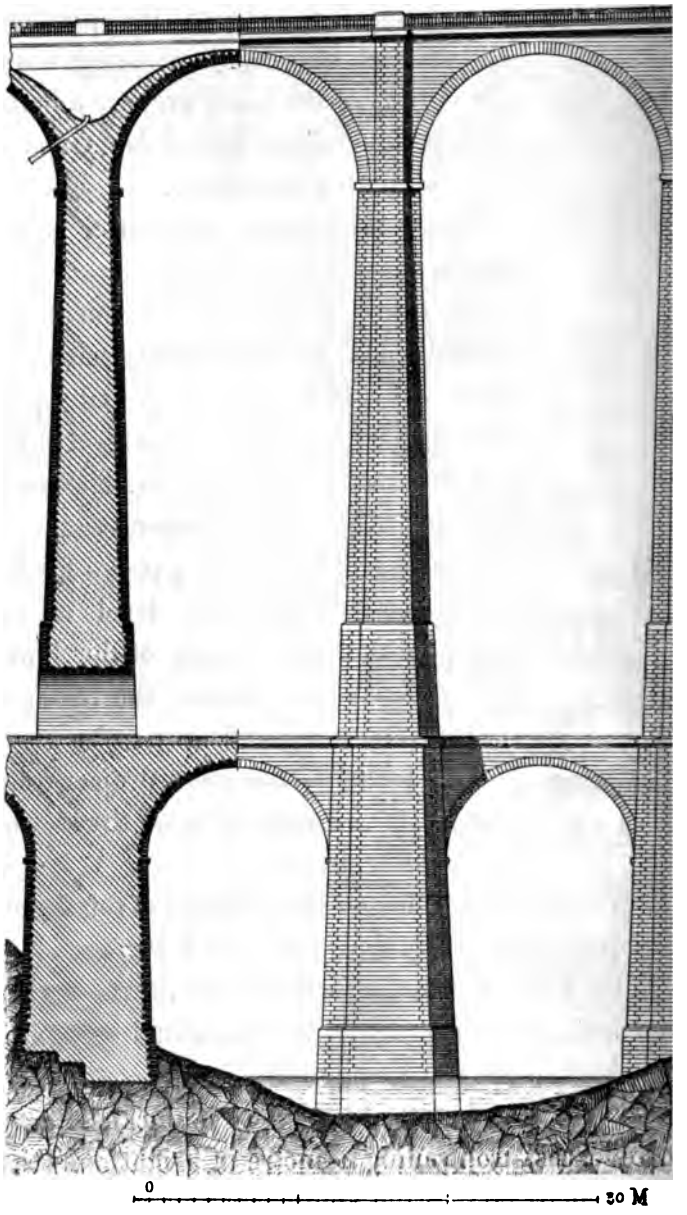
At the head facings, the piers are strengthened by counterforts having a uniform breadth of 2 metres and a projection of $0^{m},50$ between the level of the way and that of the springers. The counterforts are built with a batter of 2 p. o/o for the lateral faces and 9 p. o/o for the head faces, between the level of the springers and the crowns of the lower arches. Below the crowns, the batter is respectively, 2 1/2 and 10 p. o/o.

The socles of the piers project from $0^{m},25$ to $7^{m},50$ upwards from the crowns of the lower arches.

Owing to these arrangements, the pressure of the stone-
ork per square centimetre does not exceed $7^{k},700$.

Though the viaduct is in the form of a curve, the arches
e cylindrical, and consequently the horizontal section of
e piers takes the form of a trapezium.

The work is crowned by a cordon $0^{m},45$ in thickness, sur-
ounted by a cast-iron railing 1 metre in height, and set
dados of ashlar, laid on the abutments and counterforts
the piers.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Nature of the foundation bottom. Building materials. — The piers and abutments are laid on a solid bottom of quartzose schist, of hard consistence, cleared down to the rock and cut in horizontal benches, on which the first courses of the stone-work were laid. All the facings are in trias sandstone from the plateau of La Garde, distant 8 kilometres. The resistance offered by this sandstone, up to a crushing weight, is equal to a pressure of 250 to 300 kilogrammes per square centimetre.

The visible facings are in coursed scappled rubble; the angles of the piers, counterforts and head facings of the arches, are in coursed rubble. The cordons of the crowns of the springers and the socles of the piers, are in ashlar of the same kind as the rubble facings.

The ordinary rubble of the interiors is of quartzose schist, and was obtained from the quarries opened close to the work.

The sand which is granitic, was procured from a quarry 1 kilometre from the viaduct, and on a much higher level; it was brought to the work by means of an inclined plane. The mortar was made with finely sifted hydraulic lime from Homme-d'Armes.

Date, time and method of executing the work. —The Altier viaduct was commenced in July 1867, and finished by the end of May 1869, a period of less than two years.

Four sets of centres were employed.

After the striking of the centres, the settlement varied from $0^m,006$ to $0^m,008$. Each centre comprised four ribs, and the cubic measurement was $35^m,280$.

Two steam cranes were employed for raising the mat rials. The height was 35 metres, and the cranes, bei self-shifting, could move in a horizontal direction along temporary bridge erected 36 metres above low-wat mark.

Bulk and cost. — The total bulk of the masonry 26804 cubic metres, including 425 cubic metres ashlar.

The surface of the scappled work is 12 934 squa metres.

The surface of elevation between the natural botto and the rails (full and empty space taken together) 9530 square metres.

The total cost amounted to 845 248 francs.

From the details already given, it results that the sup ficial metre of elevation (full and empty space taken tog ter) cost 88 francs, and the average cost per cubic metre masonry was 27 francs.

The plan was prepared and the works executed, und the direction of M. Molard, engineer « des Ponts et Chau sées », sub-director of railway construction for the Par Lyons and Mediterranean Railway Company. (Southern s tem of lines), by M. Dombre, engineer in chief « des Ponts Chaussées » and of the Company; M. Jaubert, engineer the Company, and M. Torcapel, principal chief of the s tion, and at the present time engineer of the Company.

XXXIII

THE AIN VIADUCT,

NEAR THE VILLAGE OF CIZE,

BOURG AND LA CLUSE RAILWAY, DEPARTMENT OF AIN

(DOMBES AND SOUTH-EASTERN RAILWAY COMPANY.)

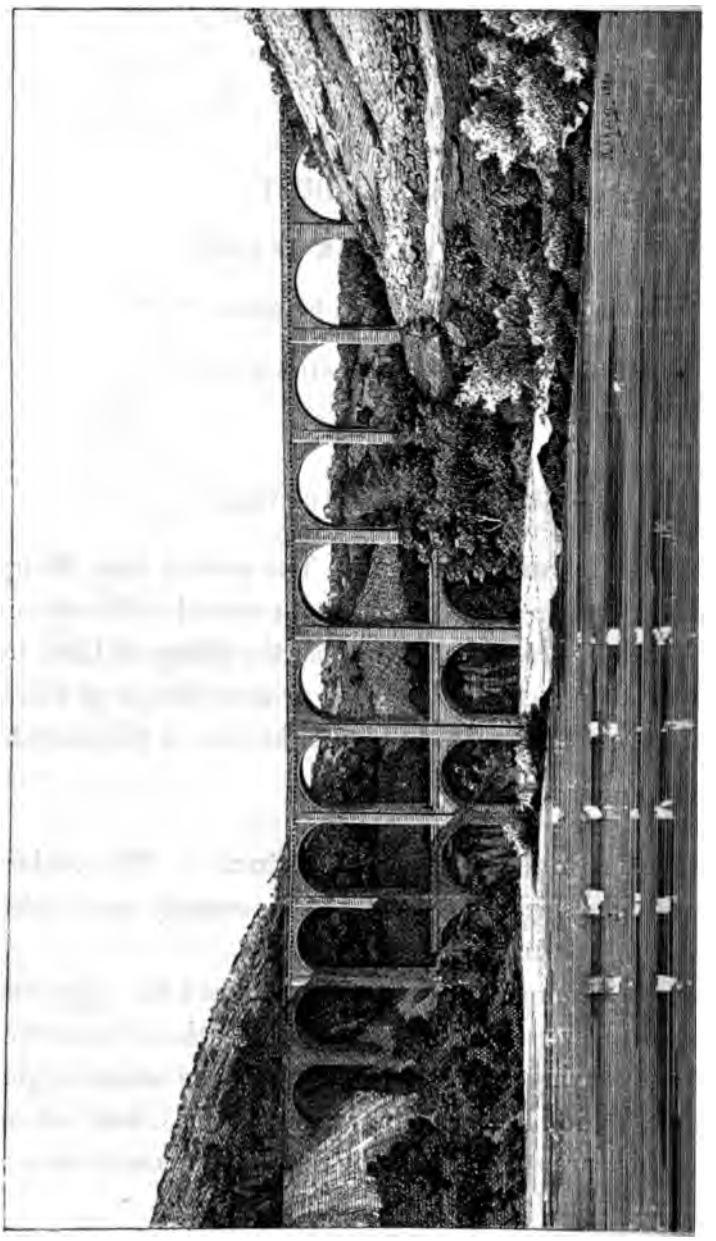
Picture. General view of the viaduct.

General arrangements. — The railway from Bourg to La Cluse, after passing through the tunnel in the mountain of Racouze, crosses the Ain near the village of Cize, by means of a viaduct $268^{m},90$, the greatest height of which is 55 metres, measuring from the bottom of the river to the level of the rails.

Actual dimensions. Description. — The viaduct was built for a single line of rails, and is entirely constructed of stone.

The work comprises two stages or stories : the upper one consists of eleven semicircular arches, each of 20 metres span, and having all their springers at the same height. They are $4^{m},60$ in breadth between the heads, and rest on piers, which are strengthened by rectangular counterforts of a uniform breadth of $2^{m},40$.

The counterforts are built with a batter of $0^{m},05$ per



metre perpendicular to the railway and a longitudinal batter of $0^{m},05$ per metre.

In plan, each pier takes the form of a cross, the arms of which are of a uniform breadth, but of different lengths, owing to the batter of the facings.

Between the shafts of the eight highest piers, is a stage or story of lower arches surbased, and forming buttresses; they have a radius of 10 metres and a breadth of 4 metres between the heads. These arches are seven in number and are crowned by a paved platform, on a level with which, and parallel to the railway, the piers are penetrated by semicircular bays of 2 metres span, which form a continuous passage.

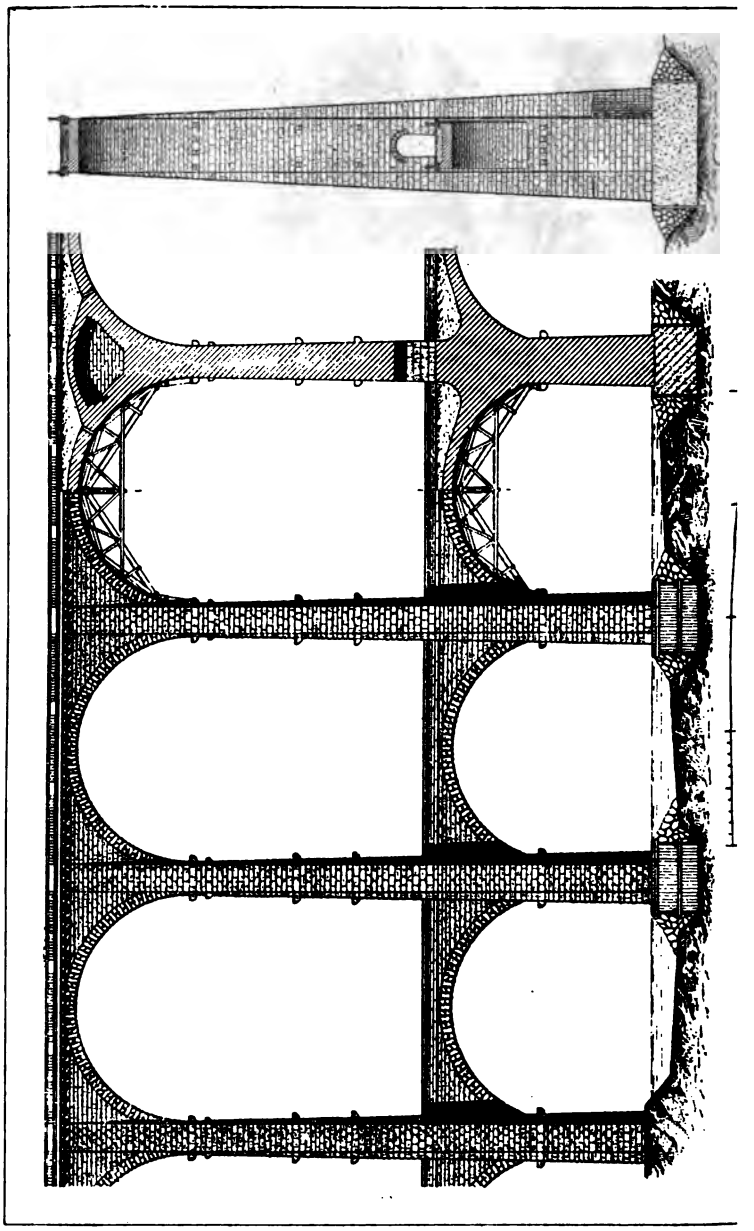
The height of this lower platform is $20^{m},90$ above the bottom of the river.

The thickness of the piers is $2^{m},80$ at the springers of the upper arches. This thickness is uniform for all the piers.

The arches are 1 metre in thickness at the key.

Above the piers, and in order to relieve the haunches of the upper arches, longitudinal arches were built, with the view of diminishing the cube of the masonry between the spandrel walls. These relieving arches are masked by the spandrels.

The abutment on the Bourg side is hollowed by means of two arches of 3 metres span. The abutment on the La Cluse side is also hollowed by six arches superposed in two rows, each arch has a span of 3 metres. All these arches are masked by the facing. The viaduct is covered by a mortar capping $0^{m},03$ thick.



The drainage is effected by means of outlets formed in e haunches of the vaults. The layer of ballast on the dis-arging arches, is $0^m,50$ in thickness, and the same on the trados of the principal arches.

The structure is crowned by a cordon in ashlar, with odillions projecting $0^m,35$, and supports a pierced or enwork parapet. The lower arches have also a parapet it it is solid.

Nature of the bottom. Foundation. — At the site the viaduct, the bottom of the river Ain consists of hard avel and round water-worn pebbles. The river piers were id on a solid mass of beton, submerged in an enclosure of les and sheet-piling.

These piers rest on a bottom composed of masses of water-orn rock, which is found at an average depth of $2^m,50$ elow the ordinary bottom of the river. The other piers are uilt on the two slopes of the valley; their foundations are id on the solid rock, at an average depth of 2 metres from ie surface.

The foundations of the river piers are surrounded by assive enrockments.

Method of construction. Materials. — The viaduct built in rubble scappled and coursed, the filling in of the terior is in uncoursed rubble. The crowns and the upper rapets are in ashlar simply scappled and picked.

The lime used for the foundations came from Theil, id that of the masonry in elevation, from Virieu-le-rand.

The cubic measurement of the masonry is as follows :

Foundation.....	817^{mc}
Elevation exclusive of parapets.....	12974
TOTAL.....	13791

The cubic measurement of the masonry in elevation may be divided as follows :

Scappled and coursed rubble.....	4674^{mc}
Uncoursed rubble.....	7994
Ashlar.....	306
TOTAL.....	12974

The works were commenced on the 4th July 1872, and completed at the end of the month of November 1875.

The construction of the viaduct necessitated the use of a foot-bridge. An American bridge was employed, and on it was laid a line of rails $0^{m},60$ gauge, for the carriage of the materials to the work. This foot-bridge was supported by sheers, resting on the offsets of piers 4, 5, 6, 7 and 8, and was bound together by braces and diagonal stays. It was constructed following the axis of the viaduct. At the top of each pier a trap was contrived in the flooring, and by means of a slide, the trucks, having movable bottoms, were enabled to discharge the mortar into the troughs of the masons.

The materials were brought on trucks, by rails of $0^{m},60$ gauge, connecting the sheds with the works. Each of these trucks carried a box hand-barrow, which was lowered on to the piers by a winch fixed on a platform, at the extremity of each group of four uprights. The materials for the arch

were lowered in the same manner, but the winch was fixed on a movable platform, which travelled on rollers, along a line laid on each side of the foot-bridge. The foot-bridge was raised as required, and the sheers were rested, at different heights, on corbels reserved for this purpose; each raising of the foot-bridge was for 8 metres.

Centres with four ribs were employed for the arches, and were supported by the corbels. Six centres were constantly used, and, in proportion as the work advanced and an arch was finished, the centre was struck and carried to another point of the viaduct. The apparatus for striking, consisted of a hollow iron cylinder, two thirds full of sand, and inside was arranged a solid cylinder of wood, which descended in proportion to the escape of the sand at the bottom. This apparatus was placed between two rows of sills or sleepers.

Superficies. Pressures. — The vertical superficies of the work (full and empty space taken together) is 9 830 square metres, of which 2 908 are for the full, and 6 922 for the empty space, measuring from above the foundations to the top of the crowns. The proportion of empty to full space is 2,38. The cube of the masonry per square metre of elevation (full and empty space taken together) is $1^{m},310$. The pressures per square centimetre, are as follows :

At upper springers	$6^{k},34$
At level of platform of lower arches	10 ,75
At level of top of foundations	10 ,15

Cost. — The cost of the viaduct amounted to

308 948f,78, which gives an average of 38f,42 per superficial metre of elevation (full and empty space taken together) and 20f,55 per cubic metre of masonry. The outlay may be divided as follows:

Foundations	34 001f,24
Enrockments	8 300,00
Elevation	266 647,54
TOTAL	308 948,78

The plans and specifications were prepared by M. Lucien MANGINI, president of the Board of Direction of the Company.

The works were executed by MM. DAPLES, LE BRUN and DALINZY, under the direction of M. Lucien MANGINI.

PORT-SAINTE-MARIE BRIDGE,

ON THE GARONNE.

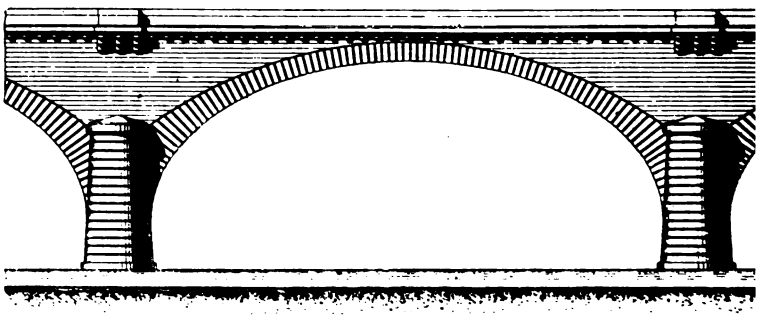
(CONDOM AND PORT SAINTE-MARIE RAILWAY.)

Site and principal dimensions. — This bridge is on the Garonne, and was built by the government for the Condom and Port-Sainte-Marie Railway (Southern system of lines). It is situated about 3 000 metres below Port-Sainte-Marie, and 7 kilometres above the confluence of the Garonne and the Lot. It consists of eight stone arches, each of which has a span of 32 metres, and the bridge consequently possesses a linear water-way of 256 metres, while the superficial water-way below the rising of the river on the 23rd June 1875, is 2 266 square metres. On the level ground which is liable to submersion, the bridge is supplemented by other works, viz.

1. On the left bank, three viaducts, each composed of a single stone arch of 16 metres span;

2. On the right bank, four viaducts; the first is formed of eight stone arches of 16 metres span; the second, of thirteen stone arches of 16 metres; the third, of an iron bay of 25 metres; the fourth, of five iron bays of 25 metres.

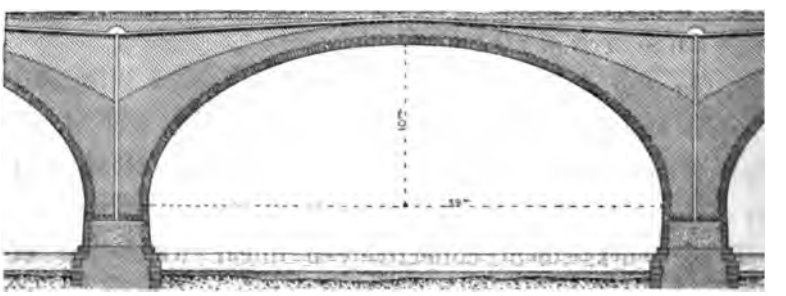
These works form collectively a linear water-way of 790 metres, and below the rising of the river in June 1875, a superficial water-way of 4 055 square metres.



Elevation of an arch.

Transversal half section of a pier.

Transversal half section of on arch.



Longitudinal section.

The arches of the great bridge are elliptical, and have a rise of 10 metres; the left bank abutment comprises, in addition, a small arch of 3 metres span, affording passage to a country road. The bridge is built for a single line of rails, and is $4^{m},50$ broad in the clear, between the parapets; the intrados of the arches is 13 metres above low-water mark, and the level of the rails $15^{m},11$.

Foundations. — At the site occupied by the bridge, the bottom of the Garonne consists of a bank of argillaceous marl, which at certain points becomes a compact sand, known in the country under the name of « tuf » (tufa); this is found either perfectly denuded, or covered with a layer of gravel $0^{m},50$ thick, at the most. The depth of water below low-water mark is from 1 metre to $1^{m},50$; but this scarcity of water very rarely occurs, and in 1876, during the whole period of laying the foundations, the depth was $1^{m},50$ or even 2 metres above it.

On the banks, the solid bottom was discovered to be at the same level as in the river, but at 5 or 6 metres below the surface and above this bottom, layers of sand and gravel were found. On the left bank, recourse was had to pumping, and in this manner, the foundations of the abutment and of the first and second piers were laid in enclosures of sheet-piling driven home by a ringing engine, previously to the commencement of the excavations. On the right bank, the foundations of the abutment and of the seventh pier were laid in enclosures formed of vertical planks, held in position by horizontal frames, and driven in by the mallet in proportion to the progress of the excavations. This system was pro-

ductive of excellent results, and was followed in laying the foundations of the relieving viaducts, to a depth of 7 or 8 metres below the surface, in the case of ground more or less watery. The two abutments and the three piers on the bank, were founded on the bed of marl, which was properly levelled.

On the river, the work was also carried on by means of coffer-dams and pumping. Great difficulties were encountered by reason of the continual risings of the river in 1875 and 1876, during which the coffer-dams and service-bridges were carried away on several occasions.

When the tufa was laid bare, holes were bored for the piles of the coffer-dams and service-bridges, and where the gravel formed an obstruction, the piles terminated in an iron bar about $0^m,50$ in length and $0^m,03$ to 0^m05 square; these piles, carefully driven, penetrated well into the tufa, and were difficult to draw, while the piles shod in the ordinary manner, and driven into the holes previously bored, were carried away by rising; the former were also liable to be overthrown, and it was necessary to surround the coffer-dams and piling of the service-bridges with massive enrockments.

The coffer-dams when finished, were filled with clay well rammed, and were easily pumped dry; for piers Nos 3 and 4, the tufa was excavated to a depth of 2 metres below the river; in the case of piers 5 and 6, the tufa became sandy, and it was found requisite to go to a depth of 6 metres and $6^m,50$ below the bottom, i. e. to 9 metres, and to $9^m,50$ below the upper part of the coffer-dams; these deep sinkings were effected by means of plank-piling of no great importance.

The pumping was accomplished by steam-power, and there movable engines were employed, one of 10 and two of 4 horse-power, driving centrifugal pumps on Neu and Dumont's system.

All the foundations were laid in masonry with rough facings.

Method of construction. — The starlings of the piers and the head facings of the arches are in large blocks of squared stone from $0^m,50$, to $0^m,35$ in thickness; the courses of the starlings and the lines of the voussoir joints are channelled.

The intrados and spandrels are in faced or scappled rubble, better described as rough stone of small size; in the intrados, of three courses of the bandeau, one corresponds to a single rubble stone, and of the two others, each to two thicknesses of rubble.

The haunches of the arches were filled in with indifferent beton, covered with a capping of ordinary beton $0^m,10$ thick; the inside of the spandrels was coated with a layer of bitumen in the same manner. The drainage is effected at the axis of the piers, by means of cast-iron pipes terminating in small arches of $0^m,60$ span, which pass through the piers below the springers.

The bridge is crowned by a plinth $0^m,35$ in thickness, resting on square modillions, and by a stone parapet $0^m,24$ in thickness. A recess for shunting is contrived above each pier, and is supported by large stone corbels, formed by three courses of masonry projecting one above another.

Materials employed. — The squared stone, with the

coursed and uncoursed rubble, came from the quarries of Vianne-sur-Baise, 7 or 8 kilometres from the bridge; the materials were carried by water as far as the lateral canal to the Garonne; they were then landed, put into trucks and taken to the works by a line of rails 1 500 metres in length.

The dressed rubble of the two lower courses of the parapet, is in stone from Chancelade, near Périgueux. Theil lime was used, and the mortar was made of 300 kilogrammes of lime to $0^{cm},900$ of sand.

Service of foot-bridges. — On both sides of the works, service-bridges were established, and fitted with rails for the working of the cranes; the up-stream bridge was also provided with two ordinary rails for the transport of materials. The flooring of these bridges was 7 metres above low-water mark. To the right of the navigable arch, the two floors were movable, and were raised, by means of winches fixed on the scaffolding, to a height of about $11^{m},20$ above low-water mark. Three travelling cranes were employed.

Centres. — The centres used in this work were of four kinds. The ordinary centre rested upon five supports; two were formed by the socles of the piers, and the three others by the rows of piling, one of which was double at the middle of the axis. During a rising of the river, it was observed that these centres acted as a barrage; free course was therefore given to the water, by removing the lower ties of the two sides of the central piling, and taking away the king-post.

The centre for the navigable arch, was an American truss, which allowed a passage of 14 metres; it rested on four supports, viz. the socles of the piers and two double rows of piles.

A fourth centre was made with the view of utilizing the timber collected for a first navigable centre, which was only intended for a passage of 12 metres. Like the ordinary centres, it rested on five supports, which being more elevated, allowed small craft to pass beneath them.

Six centres were constructed for the eight arches; those of Nos 1 and 2 were used for Nos 7 and 8.

The centres rested on sand-boxes, and notwithstanding the precautions taken to cover them with plaster and cement, it was found at the striking, that the water had penetrated to the sand, so that it was necessary to withdraw it by means of small iron hooks; nevertheless the striking was effected with great regularity. This fact is the more worthy of notice, as sand-boxes submerged by a rising of the river, before being protected in the above-mentioned manner, have been emptied and turned upside down, in consequence of which, the centre lost its bearings and was put out of shape.

The centres answered all expectations and gave excellent results. The settlement at the top, during the construction of the arch, was, on the average, about $0^m,04$ and $0^m,08$ for the centre of the navigable arch. The settlement of the arches at the striking of the centres was very slight; it varied from $0^m,00$ to $0^m,025$, and the small fissure in the extrados of some arches, in continuation of the joint of rup-

Time occupied in the execution of the works. — The works were contracted for on the 19th September 1874; the remainder of the year was employed in opening quarries and making the necessary preparations for the undertaking. In the month of May 1875, the foundations of the first pier were begun, but in June of the same year, the erections were overthrown by the rising of the river, and it was not possible to resume the excavations before July. The works commenced in the river were actively carried on during August and September; two coffer-dams were completed, as also the piles for two others, and for the service-bridges, when on the 15th September, another rising of the river entirely destroyed them. The work, continued on the banks, was again hindered by a rising in November; the construction of N° 3 pier, in the river, could not be resumed before the month of December, at the winter low-water mark, and the foundations of this pier were therefore laid in January and February 1876.

In March and April, the coffer-dams of piers N°s 4 and 5, and the service-bridges, were again carried away. The works were not resumed before June, and in July, August and September, the foundations of the three river piers N°s 4 5 and 6, of the shore pier N° 7, and of the right bank abutment, were laid. The centres were commenced in August and the masonry of the arches on the 9th September,

The works progressed rapidly, and four months later on the 6th January 1877, the eighth arch was keyed, and the centre struck on the 29th January. The execution of the spandrels followed, and the parapets were placed in November 1877. The construction of the bridge occupied

about three years, in consequence of the delays occasioned by the risings of the river.

Cost. — The cost of the bridge alone, amounts to nearly the following sums:

Contract price	780 000f
Compensation to the contractor for delays and damage caused by the rising of the Garonne.	57 000
Expenses of superintendence, including the reconstruction of works destroyed by the risings	250 000
TOTAL	1 087 000f

or about 3 500 francs per metre run of the length of the bridge; this is a high rate for a bridge with a single line of rails, but is explained by the difficulties encountered in the construction.

The plans and specifications were prepared and the works executed, under the direction of M. FARAGUET, engineer in chief « des Ponts et Chaussées », by M. PETTIT, engineer, assisted by M. MARCHAND, « conducteur ».

The contractor was M. LANGLADE (Justin).

SEVENTH SECTION.

GENERAL DOCUMENTS.

XXXV

BOARD OF GENERAL DIRECTION OF RAILWAYS.

CENTRAL RAILWAY STATISTICS.

The Board of General Direction of railways exhibits collection of volumes published at various periods :

1. *A methodical repertory of French railway legislatio* (1 volume in-4°, 5th edition 1879). This repertory presen a complete enumeration of the taxes, acts, decrees an decisions referring to railways up to the 1st August 187

2. *Situation of French railways on the 31st December of t years 1875, 1876, 1877 and 1878* (4 volumes in-4°). Th publication shows the lengths of the systems, the chron logical order of their formation, the relative lengths pe department, with the superficies and population, out lines of the principal localities served, etc. It comprise not only the lines of general interest, but those of loc and manufacturing importance. Each of these volumes cor tains a map of French railways, and the volume relatir to the year 1878 contains in addition, a map of Algeri railways, the situation of which is annexed to that of Fren

ilways on the 31st December 1877 and the 31st December 878.

3. *Financial documents concerning French railways* (1 volme in-folio, year 1868).

4. *Technical conditions of the establishment of French railays* (1 volume in-folio, year 1868).

5. *Documents relating to the construction and working of e railways* (1 volume in-4°, year 1872). The Statistical epartment of the railway service publishes, as it acquires e materials, a series of parts or numbers intended to form volume embracing the period from 1870 to 1879 and llowing the collection published in 1872.

6. *Statistical documents on the French railways relating to e years 1868 and 1876* (2 volumes in-folio). The statistical ocuments relating to the years 1868 and 1876 contain e most interesting particulars respecting the establishent and working of French railways. This information, for ch of the two years, is comprised in a series of 20 tables.

The frames of these tables are similar to those presented y M. DE FRANQUEVILLE, Director general « des Ponts et Chaus-ées » and of French railways, to the second Congress of eneral statistics, held in Paris 1855. The project of M. DE RANQUEVILLE was adopted in principle, by the Congress, s being able to serve as a type for the preparation of nternational railway statistics, by the different European States.

7. *European railways.* Comparative receipts of the years 1862 and 1861 (1 volume in-4°).

8. *European railways.* General working results (years 1862 to 1869, 5 volumes in-folio).

The Central Statistical Service of the railways is und
the Board of General Direction. It was organized in 184
by M. Teisserenc de Bort, under the ministry of M. Dum

At the present time, it constitutes a division of the Dire
tion of railway construction, under the authority of MM. V
ron-Duverger, Inspector general des « Ponts et Chaussées
Director general of Railways, and Fournié, Director of rai
way construction.

This service is directed by MM. Systermans, chief of d
vision, Cochin and Moreau, chiefs of the office.

XXXVI

DEPARTMENT OF CHARTS AND PLANS

AND GRAPHIC STATISTICS.

Charts and statistical documents.

NATIONAL CHART ON THE 200 000th. STATISTICAL ATLAS OF STREAMS OF WATER, MANUFACTORIES AND IRRIGATION WORKS.

II. WAYS OF COMMUNICATION IN FRANCE.

III. ALBUM OF GRAPHIC STATISTICS OF 1879 AND 1880.

IV. ATLAS OF THE CANALS OF FRANCE.

V. REPORT OF THE MINISTRY OF PUBLIC WORKS. STATISTICS AND LEGISLATION COMPARED.

VI. GENERAL SURVEY OF FRANCE.

I

NATIONAL CHART ON THE 200 000th; STATISTICAL ATLAS OF STREAMS OF WATER AND IRRIGATION WORKS.

A. National chart on the $\frac{1}{200\,000}$. — In accordance ith the dispositions decided on by a ministerial decree of e 23rd February 1879, the chart of France on the $\frac{1}{200\,000}$ ıblished by the Ministry of Public Works, is engraved in ıree colours, on copper. It comprises 141 sheets, each of hich is $0^m,426$ by $0^m,30$ and, taking into consideration ıe difference of the scales, accurately represents an extent

of ground equal to two sheets of the military staff map on the 80 000th.

Similarly to the sheets of this map, those of the chart on the 200 000th have the boundaries marked by straight lines at right angles to each other, one system of which is parallel, and the other perpendicular, to the meridian of Paris.

The new chart is prepared with a special view to the execution of public works, and it consequently indicates with great precision, the ways of communication of all descriptions, as also physical, agricultural, industrial or administrative circumstances, capable of exercising any influence on the direction of these ways or the progress of transport. With this object, it shows the mineral workings, the populations of villages, in which the number of inhabitants exceeds 1 000 according to the census of 1876, hydraulic works of a superficies exceeding 50 hectares, curves of level equidistant 100 metres, and the altitudes of certain remarkable points above the level of the Mediterranean at Marseilles.

In the preparation of this chart, the most recent surveys and corrections made by the engineers « des Ponts et Chaussées » have been turned to account, as also those that have been made during the last few years, by officers of the Staff, military engineers and road trustees.

B. **Statistical atlas of streams of water, hydraulic and irrigation works.** — Besides this first edition in small sized leaves, which, properly speaking, constitutes a preliminary chart, the administration also decided on the publication of another edition in large sheets,

ach of which, obtained by means of a collection of sheets tereotyped, comprises an entire department, and when nited, will form the statistical atlas of streams of water, ydraulic and irrigation works.

Circulars from 1861 to 1863 respecting the catalogue of streams of water. — The decree of the th May 1861 gave to the Ministry of Public Works the xclusive direction of the police, the purification and improvement of streams navigable neither for vessels nor rafts, nd the administration consequently recognized the necesity of preparing a catalogue of the hydraulic resources enceforth confided to its care.

On the 30th July 1861, a ministerial circular was addressed to the engineers requiring them to fill up two tables ndicated by the letters A and B. The first of these tables so the circular was worded) is an outline which may include all details necessary to arrange in a system, the streams navigable neither for vessels nor rafts, their length, breadth, discharge, etc. With the exception of particulars relating to a small number of water-courses, which may undergo a change, according as the bed of the stream is regularized or improved, the information contained in this table ought to assume a character of permanence similar to that of the natural phenomena, of which it is the condensed expression. On the other hand, the second (devoted to hydraulic and irrigation works), will be modified for each valley, and will enable the progress of industry to be followed step by step according to its development.

Other circulars of the 27th March 1862 and 23rd June

1863 emphasized the instructions of that of 1861, and required that the first work should be supplemented by a chart containing the principal indications of tables A and B.

In order to make these documents correspond to each other and to centralize their publication, the administration, by a decision of the 22nd January 1869, instituted under the presidence of M. PERRIER, Inspector general, a special commission which, by a decision of 23rd June 1879, was attached to the department of Charts and Plans, and continued to exercise a special supervision over the execution of the work.

In a circular issued at the commencement of 1870 to the engineers of the hydraulic and navigation service, the Commission made an appeal to them for assistance in a publication, which « was to be (so said the circular) the work of the corps « des Ponts et Chaussées » collectively, » and requested them to furnish detailed information, in the form of maps and statistical returns upon all subjects connected with irrigation.

Though interrupted by the events of 1870 and 1871, the works of the Commission have since been resumed and pursued with all the activity consistent with the preparation and engraving of plates, the impression of the pictures, and especially the repeated and attentive revision of all the documents before accepting them definitively.

Atlas on the $\frac{1}{200000}$th. — The departmental charts are obtained, as has been already stated, by the union of the sheets of the chart on the $\frac{1}{100000}$th. They are completed by the detail of the hydrographic system, and by numbering each stream in regular order, according to the method of

lassification indicated by the circular of 1861. There will also e found hydraulic works, heads of water, irrigation canals nd surfaces irrigated. Conventional signs correspond to he principal cultures.

The proofs are sent to the engineers of departments, after eing submitted to the most careful revision. The impres- ion is not worked off until the second proof has undergone his double inspection.

Statistical Tables. — The Atlas is accompanied by statistical Tables also prepared for each department. The streams follow each other in the order adopted for the classification of the hydrographic system, and bear numbers identical with those in the corresponding map. To facilitate their knowledge and use of these tables, they are preceded by a summary notice explaining the system upon which they are prepared, and followed by an alphabetical index, defining by its coordinates, the geographical position of the confluent of each stream.

With regard to the proofs of the tables, the same proceeding is adopted as for the maps, the Commission desiring that the merit and responsibility of the work should belong to the local engineers.

Notices on irrigation. — Notices with plates are annexed to the Atlas and to the Tables, and refer to the best types of irrigation adopted in each locality. The Commission has already received many useful documents upon the subject and is preparing to publish them.

General introduction. — In a general introduction,

the Commission will recapitulate the results contained in the Atlas and Tables, and while comparing the methods of irrigation followed in the various districts, will point out the technical and systematic measures that scientific experience has suggested for the better utilization of water.

Personnel. — The engraving was in the first instance confided to M. DULOS, and since his death (in 1874) it has been executed by his successor M. HELLÉ.

The preparation and revision of the maps are carried on by M. BARDOUX « conducteur », and several « conducteurs » and draughtsmen under his direction.

The statistical Tables are in the press at the National Printing Office.

The Commission exhibits the maps and tables of the departments of the Haute-Garonne, the Ariège and the Nièvre, as specimens of this publication. The others will follow without delay.

Importance of the impression. — The impression will be sufficiently important to be adequate to the requirements of the departmental services, and also to be offered to the general public at a moderate cost. The copper plates being the property of the Administration, can at all times be adapted to new conditions or improvements, the necessity of which may be recognized.

The departmental Atlas is very carefully executed, and has long been required. As it is rendered complete by the statistical tables, it will constitute, according to the original idea, a veritable catalogue of our hydraulic ressources, and

will enable them to be studied with a view to their utilization. Public opinion has hitherto shown a certain indifference to these questions, but at the present time it commences to recognize their importance, and improvements with reference to the management of water, are included by the Government in the programme of the great public works. The publication of the statistical Atlas of streams of water, hydraulic and irrigation works, consequently takes place at the most appropriate period, and will aid the onward movement which cannot fail to be made, in developing the riches of our country.

II

CHARTS OF THE WAYS OF COMMUNICATION.

This group comprises the annexed charts :

A. **Chart of the principal ways of communication in France on the $\frac{1}{500000}$th** (in 6 sheets large map size). — This chart comprises the national and departmental roads, railways in operation, forest and agricultural roads, and the hydrographic survey.

B. **Chart of the principal ways of communication on the $\frac{1}{1250000}$th** (in 2 sheets). — This chart is a reduction of the preceding one in 6 sheets, but it gives, in addition, the hydrographic basins and the figure in relief of the principal mountains.

C. **Chart of the French railways on the $\frac{1}{125000}$th** (in eight colours). — This chart shows in different colours

all the systems of railway lines, either finished or in course of construction, belonging to the great or secondary companies, the lines classified or decreed, and the foreign railways. All stations are indicated, and local systems are traced in black.

D. **Chart of internal navigation on the $\frac{1}{1\,2\,5\,0\,0\,0}$th** (in eight colours). — On this chart are shown the hydrographic survey, basins, mountains, existing canals, and those declared of public utility, summit lines of the principal basins, and the portions of rivers navigable for vessels and rafts. Special tints designate the navigable ways administered by the State or granted to companies, the canalized rivers, and the fluvial and maritime navigation at the embouchures of rivers.

Among the innovations contained in this new edition, may be pointed out the indication of the luminous range of the lighthouses, and the outline of the principal canals of irrigation.

As in the preceding chart, the foreign countries are tinted and the contrast brings out clearly the surface of France.

E. **Chart of national roads on the $\frac{1}{1\,3\,9\,0\,0\,0\,0}$th** (in four colours). — With the exception of the two first, these various maps are executed in chromolithography by M. Regnier, printer. This method has been recently adopted for the geological chart, and had become necessary in order to respond to the demands of the great departments of the State, and the numerous commissions instituted during the last few years. In addition to which, the cost is thereby reduced, so that these charts may be sold by the differe

booksellers at a very moderate price. These documents are therefore within the reach of the general public, an advantage of comparatively recent date. The plates and stereotypes belong to the Administration, and are constantly receiving additions, according to the progress of the lines as they are classified, declared of public utility, and opened for traffic.

III

ALBUMS OF GRAPHIC STATISTICS FOR 1879 AND 1880.

Advantages of graphic statistics. — The system of graphic statistics is of very recent date, but the domain and range of its application are daily extended. At the present time, there is scarcely a branch of human activity in which recourse is not had to its services. In fact, it successfully meets a twofold want of the age, which requires information to be supplied with accuracy and expedition. Now the graphic methods fulfil both these conditions excellently; not only do they enable us to comprehend at a glance a series of phenomena, but also to point out the relations and anomalies, which exist between them, to detect their causes, and to discover and elucidate the laws which regulate their action. They advantageously replace the long tables of figures formerly in use, so that without detriment to the correctness of statistics, they extend and popularize the benefits derived from them.

The corps « des Ponts et Chaussées » may with good reason claim an important share in the employment and general diffusion of these methods. M. MINARD was one of the

first to apply them, and by his excellent works, he ha illustrated their flexibility and universality of adaptation M. LALANNE, Inspector general, Member of the Academy o Sciences, has on his part, elevated the scientific range o these methods, and through his instrumentality, remarkabl progress has been made in calculation by lines and figures

Not only does this method address itself to the sense simultaneously with the mind, and depict to the eye fact and laws that would be difficult to discover in long an complicated numerical tables, but it possesses the additiona merit of avoiding the obstacles which restrict the genera diffusion of scientific works, and which arise from the diver sities presented by the customs of different nations, i respect to their scientific idioms and systems of weight and measures. In the method now under consideration, thes obstacles have no existence; a diagram is neither German nor English, nor Italian; its relations of measure, surface and colour, are comprehended by all. The system of graphi statistics constitutes therefore a species of universal language which offers to the learned world facilities for the free in terchange of ideas and discoveries, without distinction c country, and to the immense advantage of scientific research

Impressed with these facts, the Minister of Public Works fully appreciating the importance of this mode of graphi representation, added, by a decree of the 12th March 1878 a department of graphic statistics to the Direction of Chart and Plans.

By this decree, the new department is charged with th preparation of figurative charts and diagrams, expressing i a graphic form, statistical documents relative either to pas

senger or goods traffic on all descriptions of lines of communication and in sea-ports, or to the construction and working of these ways; in a word, to all economical, technical, or financial facts which appertain to statistics, and may therefore concern the Ministry of Public Works. It was also decided, that an annual collection of the charts and diagrams should be made in an album of portable size, intended for distribution to the Chambers in the course of the session.

The first application of this measure was the production of the album of 1879. It contains twelve plates, described in the following list:

1. Tonnage of rivers, canals and ports (1877).
2. Tonnage of national roads, latest returns (1876).
3. Tonnage of railways (1877).
4. Railways receipts (1877).
5. Financial history of the Northern Railway Company (1845-1879).
6. Financial history of the Eastern Railway Company (1845-1879).
7. Financial history of the Western Railway Company (1843-1879).
8. Financial history of the Orléans Railway Company (1843-1879).
9. Financial history of the Paris, Lyons and Mediterranean Railway Company (1835-1879).
10. Financial history of the Southern Railway Company (1845-1874).
11. Arrivals and departures of vessels in commercial ports (1868-1877).
12. General and special commerce of France (1828-1879).

The album for 1880 has just appeared, and, in comparison with that of 1879, shows a certain progress in rela-

tion to the number and interest of the plates, as also in th quality of the execution.

A few quotations from the index will show the diversit of the subjects contained in this album.

I. STANDARD CHARTS.

1. Tonnage of rivers, canals and ports in 1878.
2. Tonnage of national roads in 1878.
3. Tonnage of railways in 1878.
4. Gross receipts of railways in 1878.
5. Net receipts of railways in 1878.
6. Gross receipts of stations in 1878.
7. Conditions of navigability of navigable ways in 1878.
8. Receipts of Paris omnibuses in 1878.
9. Receipts of Paris tramways, passenger steamers and the Sub urban Railway (Chemin de fer de ceinture) in 1878.
10. Receipts of Suburban Tramways of Paris in 1878.

II. SPECIAL CHARTS.

11. Technical conditions of the establishment of railways.
12. Cost of the first establishment of railways.
13. Cost of the first establishment of the navigable ways of Franc and the ports.
14. Data relative to the maintenance of the national roads i 1878.
15. Development of ways of communication of all descriptions, i each department.
16. Development of railways in the principal States from 1830 t 1878.

It would be useless to commence a detailed descriptio of these plates, since no explanation could do them justice or be properly substituted for an examination of them. No that the bases of this publication are definitively arranged

continued with perseverance in the same spirit, there is o doubt but that it will render important services to the :onomist, the statesman, and in short, to all those who are :cupied with the grave and arduous problem of the rela- ons between the development of the national riches and ıe progress of the public works.

IV

ATLAS OF THE CANALS OF FRANCE.

Circular of the 29th november 1854. — The Admin- tration, having fully recognized the utility of bringing 'gether in one complete collection on the same scale, the rawings of canals open for traffic, issued a ministerial cir- ılar on the 29th November 1854, requesting the engineers ı chief of the navigation service to lose no time in applying ıemselves to this undertaking, and the programme of the ork was traced as follows :

Each canal to be represented by a plan on a scale of $\frac{1}{200000}$th nd a longitudinal section, prepared on the same scale for ıe lengths, and on the $\frac{1}{1000}$th for the heights. The plan and ection to correspond on the same sheet, and to be comple- ed on this sheet, or others annexed, by cross sections and rawings of the works of art on a scale of $\frac{1}{200}$th.

The size adopted was 0,60 by 0,90.

The execution of the Atlas was committed to the engineer n chief, Director of the Dépôt of Plans and Charts.

Commission of 1859. — Some years afterwards, on the 5th May 1859, a high commisson of inspectors general

was appointed under the presidence of M. Mary, Inspector general, for the purpose of perfecting the work and of investing it with additional importance.

In announcing this measure to the engineers in chief, the ministerial circular of the 21st december 1859 dwelt upon the importance attached by the Government to the Atlas in course of preparation : « Not only was it to contain the work appertaining to each canal, but all those worthy of notice on account of their special characteristics, whether in respect of the difficulties surmounted, or the possibility of applying them to other localities. » Twelve plates have already been published and distributed (continued the circular), and by the scrupulous care exercised in their preparation and execution, as well as in the improvement they successively manifest, it will be recognized that the Ministry intends to make this collection a really beautiful and useful work, possessing unusual significance from an historical and technical point of view.

The Commission of the Atlas of canals exercised its functions for nearly two years, but ceased to meet after the retirement of the president 1st January 1861. Since that period, the work of examining the drawings and of preparing the plates, has been pursued on the same principles, but under the exclusive care of the successive directors of the Dépôt of Charts and Plans.

Details of execution. — The number of plates composing the collection is 89. They are engraved on stone, with great care, by the firm of Régnier, and when 300 impressions are taken, the engraving is effaced.

In consequence of a larger distribution being demanded for the requirements of the service, some plates have been prematurely exhausted, and it has been necessary to have recourse to photo-engraving on zinc, to complete the collections.

This operation was entrusted to M. GILLOT, engraver, who accomplished the work with success.

The dispositions enjoined by the circular of the 29th November 1854 have been respected, with the exception of some unimportant variations, and a remarkable unity of design is observable throughout the collection. When dates are consulted, it will be remarked that the earlier plates have a great deal of style, and are not sufficiently filled.

On the other hand, in proportion to the progress of the publication, more attention has been paid to the condensation of the figures, and to completely filling the plate, and in this manner they are rendered more interesting and less numerous.

At the same time, and as a natural consequence, the average cost (including engraving, paper and impression of 300 copies) has been augmented from 500 to 700 francs.

Cost. — The total expense, up to the present date, is about 60 000 francs, which sum represents an average of 200 francs for a complete collection, 674 francs for a plate, and 2f,25 for each sheet of the Atlas. The importance and success of the undertaking being considered, this outlay will not appear extravagant.

Index. — For the purpose of facilitating research, two

indexes have been placed at the commencement of the Atlas: one, in which the canals are arranged by series, and which forms a distinct group; the other contains all the names of the navigable ways, arranged in alphabetical order.

Annexed documents. — Following the plates, or correctly speaking the Atlas, will be found, in the form of general documents, a chart of internal navigation with figured maps, representing the tonnage on the navigable ways and their conditions of navigability. These plates, and particularly the two last, do not present the same finish of execution as those of the Atlas, their special object being considered; nevertheless they appeared sufficiently important to be attached to it, and to supplement the information there contained.

Present and future state of the work. — At the present time, the collection comprises all the navigable ways actually completed, except the canals of La Rochelle to Marans, the Sauldre, Coutances and Saint-Louis.

The plates of these canals are in course of preparation and will appear in a second part, as also the Haute-Marne and Eastern canals; this enumeration does not include other canals, the general outline of which has been traced by the Administration, and the plans and specifications will shortly be submitted to the approval of the public authorities.

The Atlas of the canals, which is an inventory or catalogue of our system of navigation, is intended to follow the successive developments of navigable ways, and can only be finished when these ways have received their definitive

mplement, a period which must doubtless be still very mote. Till then, the collection will remain open; in the ean time, the surveys and works actually undertaken the engineers, give promise of abundant materials, and e period now commencing, will doubtless enrich the col-ction with valuable additions.

V

REPORT OF THE MINISTRY OF PUBLIC WORKS.

A ministerial decision of the 14th January 1880, ordered at a monthly Report of the Ministry of Public Works ould be published, analogous to that of the Ministry of nance, and that it should be prepared by the department Charts, Plans, Archives and Graphic Statistics.

This Report is not to be an organ of discussion or tech-ology, but a collection of statistic and legislative inform-ion, similar to the Album of graphic statistics before entioned (III); it is specially intended for the Parliament, nd furnishes monthly, in a condensed form, the most recent ocuments and figures, disseminated in a great number of rench and foreign publications, which owing to the con-itions of their issue, can only appear at long intervals.

Notwithstanding the care taken to exclude from this eport all data not absolutely authentic, it is still possible at some calculations may possess only a temporary cha-acter, and may be susceptible of revision, and this contin-ency must be attributed to the rapid publicity, which has ecome a requirement of the age. It will therefore still be

necessary to seek the definitive figures in these importan publications, which already possess a legitimate authority and could not be replaced by a Report.

A special article is devoted every month to approve railway tariffs, and the publicity thus assured to these tariffs gratifies a wish long expressed in the commercial world.

With respect to foreign matters, it is preferred to publis in this Report, documents having immediate reference t questions relating to public works.

At the end of each of the two divisions of the Repor will be found, under the head of *miscellaneous communications,* much information upon various subjects concerni France and foreign countries, which, without having an of cial character, may nevertheless present a legislative o statistic interest.

From time to time, diagrams inserted in the text, will illustrate certain tables of figures, and aid in the explanation of the graphic statistics, the diffusion and services of which have already been explained.

The Report appears in the first fortnight of every month, and contains a complete table of certain categories of facts corresponding to the preceding month (opening of lines, homologation of tariffs, declaration of public utility, etc.)

Each number contains four or five sheets, and the work forms two volumes a year, each of which has its own paging and alphabetical index of contents.

VI

SURVEY OF FRANCE.

Bourdaloue survey. — This was executed twenty years ago, and extends to a system of 14980 kilometres. The results are recorded in a collection in three columns, which indicates the position of each bench-mark.

General survey of France. — Owing to the very limited range of the system of triangles, this operation, which has been productive of great benefit, was inadequate to the requirements which demand a knowledge of the relief or prominences of the country. The time is now arrived to commence an undertaking in which the whole territory will be embraced in one triangulation.

Central Commission. — By decrees of the 5th October and 20th December 1878, the Minister of Public Works, after consulting the Minister of the Interior and the Minister of War, appointed, under his own presidence, a central Commission, composed of delegates of the three Ministries, and entrusted to them the task of determining the bases of the general trigonometrical survey.

Local Commissions. — The Commission recognized from the first, the necessity of obtaining from the departments the assistance required to facilitate the work, and a circular of the 25th November 1878, requested the prefects to appoint commissions to be presided over by themselves, and to include two members of the general council and

other persons designated by their competence and statio in addition to the heads of the different administrations.

Report of the survey. — From the moment of the appointment, the local commissions applied themselves the work of compiling a report of the survey, that is to sa the extent of the surveys already made, and an account the ressources at the disposal of the departments, in respe of instruments and operators.

Inquiries abroad. — The Central Commission havi thus obtained information in France, wished to enlarge t sphere of inquiry, and consequently ascertained that England a survey had been made of two thirds of the te ritory; in North Germany of two fifths, and that in Belgi and Switzerland, it was nearly terminated.

Programme of the general survey. — After th preliminary measures, the Commission drew up the p gramme of the general survey of France, with a vi to the requirements of the present and the future, and the same time, availing itself of the most recent improv ments accomplished in enterprises of this nature.

This programme comprises, in the first place, a surv of great precision, which is to include all descriptions ways of communication, and the principal streams of wate In the second place, it makes provision for intercalary su veys, which, again intersecting the interior triangles of th first system, will permit curves of level to be traced, an thus define the relief.

Independently of the catalogue, which will show the results n the operations in the form of tables, a graphic reper- ory, an abridged chart, on a scale of the $\frac{1}{10\,000}^{th}$, will be prepared by the aid of the survey plans, in which each point vill be marked in its place, and the curves of level will be epresented. These data can be afterwards utilized for the complement of the charts existing or in course of publication, as also for the preparation of others that may be under- aken by the State or by private individuals.

In this programme, the survey applies to an approxima- ive length of 840 000 kilometres, which are thus divided.

National roads	37 330
Departmental roads	42 240
Roads joining high roads	95 570
Roads of general interest	75 200
Ordinary roads	390 410
Canals	4 750
Railways of general interest (including the complementary system)	40 000
Railways of local interest	4 500
Rivers navigable for vessels and rafts	16 000
Streams of water of which the superficies of the basin exceeds 2 000 hectares	134 000
Total	840 000

In this total, the Bourdaloue survey already executed, measures a length of 15 000 kilometres as before mention- ed, and will be completed by a survey of base lines of 25 000 kilometres, which is to be executed with the most perfect accuracy that can be attained in these fundamen- tal operations.

These data enable the Central Commission to calculat that, by utilizing the surveys already made, and by securin the assistance of the various officials, the work can be ac complished in ten years at the most, and that the total ou lay will be 19 millions.

Departmental assistance. — The departments i which the roads and communications are surveyed, ar where communal or private entreprises of irrigation or sar tary improvement are being carried out, could not be l without some share in carrying out the work. Accordingl two circulars were issued, one from the Ministry of Pub Works (11th July 1879), the other from the Minister the Interior (12th July 1877), in which the prefects we enjoined to make known to the general councils, that th assistance would be required, with the view of lessening t expense to the State, and that the departments would expected to take an interest in a work from which th must necessarily derive considerable advantages.

The amount of the financial assistance required, w fixed at 3500000 francs (or a little less than a fifth of t total expense), to be divided in proportion to the amount the departmental rate. But this charge will be considerabl diminished by the contributions of the vicinal roads, whic will greatly assist the departments, both in the term payment and the rate of interest for the loan.

The general councils have cordially received this appeal i favour of an enterprise of such paramount importance t public and local interests.

During the August session, thirty-four voted more tha

1 200 000 francs of the subsidy required, and many councils only await further explanations, and permission to charge the expense to the vicinal roads.

Grant from the budget of 1881. — The Government had no hesitation in asking Parliament to sanction this essentially national work by a vote of credit, and thus to give encouragement to an undertaking calculated to aid France in the recovery of much time lost, while her neighbours were prosecuting an enterprise in which others had only followed in her steps.

It is with this view that a credit of 500 000 francs has been put down in the budget of 1881 (section III, chapter XX).

Preliminary project of the system of base lines. — The delegation of the Central Commission, on its part, continued the work under the presidence of M. MARX, Inspector general, and studied the preliminary project of a system of about 25 000 kilometres of base lines, divided amongst the different ways of communication, as follows :

NATURE OF OPERATIONS.	RAILWAYS.	CANALS and RIVERS.	NATIONAL ROADS.	DEPARTMENTAL ROADS.	VARIOUS ROADS.	TOTALS.
Primordial operations....	11 820	275	1 365	385	12	13 857
Intermediary operations..	3 075	//	4 649	2 893	152	10 769
TOTALS.....	14 895	275	6 014	3 278	164	24 626

This first work simply constituted a preliminary project,

susceptible of improvement after a revision made upon th ground, and a circular of the 25th March 1880, require the local commissions to commence an investigation whic will permit the question to be viewed more closely, and th system of base lines to be definitively determined.

Documents exhibited. — In order to give an idea c this great undertaking, which gives promise of importar results, the Director of Charts and Plans exhibits the repoi of the first session of the Central Commission of the surve of France, and the chart on the $\frac{1}{2\,000\,000}$th, which shows a the same time, the Bourdaloue survey, the system of funda mental lines, and the outlines of the geodetic triangulation which is of the most perfect description.

Personnel of the Direction of Plans and Chart. — The Direction of Charts and Plans is composed as fo lows :

Director, M. Cheysson, engineer in chief « des Ponts Chaussées ».

Chief of division, M. Charle.

Heads of the office, MM. Hugo and Morel.

Among the draughtsmen, whose assistance has been mc valuable in the preparation of the charts exhibited, may l named MM. Monsel, Guillot and Bourjon.

XXXVII

« ÉCOLE NATIONALE DES PONTS ET CHAUSSÉES. »

COURSES OF LECTURES PRINTED AND LITHOGRAPHED,

AND A COLLECTION OF DOCUMENTS.

The « École des Ponts et Chaussées » was established for the training of engineers intended for the Government service and forming the national corps « des Ponts et Chaussées [1] ».

Engineer students. — The engineer students are taken exclusively from pupils that have finished the course of education at the Polytechnic School [2].

The system of instruction comprises: the construction of roads, bridges, railways, canals, maritime ports; the improvement of rivers; civil architecture; applied mechanics (resistance of materials and hydraulics); steam-engines; agricultural hydraulics; the geological and mineralogical knowledge indispensable to engineers; administrative law; political economy and fortification [3].

[1] See, in the number of documents exhibited, the Notice on the « École des Ponts et Chaussées », also some remarks in the Translator's preface at the commencement of this volume.

[2] Decree of organization 13th October 1851, articles 1 and 3.

[3] This last course is specially intended for these of the Government engineer students who are required by military law to become officers of the reserve and the territorial army.

These normal courses of instruction are supplemented by a certain number of conferences, bearing upon the subjects of study: Working of railways, electric telegraphy, photography, pisciculture, vicinal service, sanitary improvement of towns, etc.

The internal course of instruction pursued in the «École» embraces the following subjects :

1. Graphic works, drawing, shading, preparation of papers and competition on projects of works of art and construction;

2. Manipulation and trials of materials of construction;

3. Levelling and surveying; drawing plans of machines and buildings;

4. Visiting manufactories.

The course of study lasts three years.

The lectures commence in the early part of November.

At the close of the month of May, the engineer students are sent into the departments to be exercised in engineering studies under the direction of the chief engineers of the service.

This experience is continued till October[1].

Private students. — In addition to the Government engineer students, the «École des Ponts et Chaussées» receives both French and foreign private students. After passing an examination, these students are admitted to

[1] Decree of organization, 13th October 1851, article 3.

attend the lectures, and to participate in the course of internal instruction followed at the «École»[1].

Free students. — Besides the private students, others may be admitted as auditors (*auditeurs*) of the lectures, and may follow the course, on obtaining the permission of the Director of the «École».

Preparatory course. — In order to enable French or foreign candidates to pass the preliminary examination, a preparatory course has been instituted for the benefit of young men desirous of admission as private students[2].

The preparatory course of study continues for a year, and comprises:

1. The differential calculus, the integral calculus and mechanics;

2. Physics and chemistry;

3. Descriptive geometry, stereotomy and the elements of architecture;

4. Linear drawing, model drawing and shading.

All the candidates for admission must pass a preliminary examination, both for the preparatory course and for the position of private student. This examination is obligatory, even if the candidate possess a diploma or brevet of competency.

[1] See, in the number of documents exhibited, the conditions required for the admission of private students, also the conditions for admission to the preparatory course.

Services attached to the « École ». — In juxtaposition with the first and most prominent responsibility, viz. that of instruction, it appertains to the province of the « École des Ponts et Chaussées » to come to the aid of engineers, and even of the general public, in all matters of a scientific nature. With this view, certain services are annexed to the institution, and may be appropriately noticed here.

Library. — The « École » possesses one of the richest collections of works relating to engineering science, the number of volumes contained in the Library, being not less than 40 000 volumes. A printed catalogue and a double manuscript index have been compiled by the librarian, M. SCHWEBELÉ, and by their aid, researches are pursued with ease and promptitude.

Engineers are admitted at all times and at any hour for the purpose of consulting works or manuscripts.

Under certain conditions, engineers not residing in Paris, are authorized to borrow books from the library.

Galleries of models. — The galleries of the « École » contain at the present time, more than twelve hundred models or designs, divided into eleven categories, corresponding to the various courses of construction. Many of these models are of great value, and possess a special interest, in consequence of the delicacy and excellence of their construction.

A summary description, in a special notice of each model, is given in a general catalogue; if a model is a repro-

duction of a work of art, the catalogue indicates the principal dimensions, the date, the cost and the names of the engineers and constructors that assisted in the work.

The compilation of this catalogue is due to M. BARON, engineer in chief, and specially charged with the superintendence and order of this gallery.

Office of designs and drawings. Photographic studio. — The origin of this office is contemporary with the establishment of the «École» and the principal duty performed here, is the preparation of all draughts or designs necessary for demonstration in the amphitheatre, or for the publication of the lithographed lectures.

With the aid of its new and powerful auxiliary, the photographic studio, this office is employed simultaneously in preparing the periodical publication known under the name of «Portfolio or Collection of designs distributed to the students», and in compiling the Atlas of the ports of France, the first four volumes of which appear in the exhibition of the Ministry of Public Works.

The same office performs the additional work entailed by the different universal exhibitions. In fact, the organization of the exhibition of the Ministry of Public Works has always been carried out by the «École des Ponts et Chaussées».

The direction of this important service devolves upon M. DE DARTEIN, engineer in chief, assisted by M. CHOISY, engineer. M. BOULARD, as chief of the draughtsmen, and M. HUGUENIN «conducteur,» as chief of the photographic studio, are also attached to this service.

Dépôt for instruments of precision. — The object of this department of the «École», is to preserve, and to keep in good condition, the instruments used by the students for land work. The operations of this department have been greatly extended, and they now embrace orders for new instruments, and the reception and repairs of all instruments granted by ministerial decision to the engineers in France and the colonies, who may require them. In addition to which, the «dépôt» receives and stores the instruments for which engineers have no further use. These instruments are thoroughly repaired, and forwarded to places where they are required.

M. Durand-Claye, engineer in chief, assisted by M. Klein, «conducteur,» superintends the purchases, repairs and forwarding of instruments.

Dépôt of machines. — The dépôt of machines corresponds to a requirement of the same kind. It orders, receives and forwards all machines and apparatus, the purchase of which is requested by engineers, and approved by the Minister. In it are centralized and stored the most valuable materials that are left without any definite use, when works are finished.

M. Léon Durand-Claye, aided by M. Klein, «conducteur» has charge of this dépôt.

Experimental workshop at the Trocadero. — The scientific instruction of the courses of lectures is completed every year, by a series of experiments calculated to give to the students practical notions respecting the ele-

ments of construction. This was the object of the establishment of the experimental workshop at the Trocadéro. In addition to this, it encourages the progress of the science of construction, by furnishing the professors of the « École » and other engineers with the means for study and experiments, difficult to procure in any other way without considerable expense.

The organization of the experimental workshop at the Trocadéro was commenced in 1867; it is now nearly completed, and was executed under the direction of M. HERVÉ MANGON, engineer in chief, Member of the Academy of Sciences and at that time Professor of the « École ».

Laboratory. — After the fine discoveries of Vicat, it was considered necessary to familiarize the engineer students with chemical analysis as applied to the materials of construction. With this view, a small laboratory, established in 1845, was soon utilized, for the purpose of furnishing engineers with the necessary information upon chemical or physical subjects, relating to their particular branches of service. The results obtained were sufficiently important to decide the Government to order the definitive organization of an office for assaying, to be annexed to the laboratory devoted to the manipulations of the students of the « École des Ponts et Chaussées ».

The laboratory annexed to the « École des Ponts et Chaussées » undertakes all chemical analyses and assays, relative to materials of construction, and substances connected with agriculture, especially researches applying to lime, cement, mortar, plaster, building stone, bricks, clay, sand, potable

water and water for irrigation; arable soils, manures improvements.

The researches of the laboratory are not carried on the exclusive advantage of the government engineers; vate individuals may also have recourse to them in cas need. It is only necessary to send a written application to Director of the « École des Ponts et Chaussées », Rue Saints-Pères, N° 28, enclosing a sample of the substa to be analyzed. The results of the process are transmi gratuitously to the person making the application; he only to pay the expenses of correspondence.

The time occupied in examination of the sample, va according to the nature and importance of the result be ascertained, and the state of the work in the laborat the period averages from two to six weeks.

From the date of its establishment, to the close of 18 the laboratory has received 5 096 applications for anal or experiment, comprising nearly 23 000 samples.

During the last six years only, 1 492 applications ha been examined, having reference to 7 176 samples, divi ed as follows :

Limestone, lime, cement, mortar, plaster.....	3 277
Clay, sand, puzzolana, bricks.....	729
Arable soils, manures and means of improvement.	1 327
Potable water; water for irrigation, sewerage water.	1 283
Products not included in the preceding categories.	560
TOTAL.....	7 176

The laboratory was organized and directed, till the clos 1872, by M. HERVÉ MANGON, Member of the Academy, en

neer in chief «des Ponts et chaussées», and at the present time Director of the Conservatory of Arts and Trades (*Conservatoire des arts et métiers*). From 1865, the assistant of M. MANGON was M. Léon DURAND-CLAYE, at this time engineer in chief «des Ponts et Chaussées», who succeeded M. MANGON in the direction of the laboratory.

NOMENCLATURE OF DOCUMENTS

RELATING TO THE ORGANIZATION

OF THE «ÉCOLE DES PONTS ET CHAUSSÉES.»

AND TO THE COURSE OF INSTRUCTION FOLLOWED THERE.

I. ADMINISTRATIVE DOCUMENTS.

(DOCUMENTS COLLECTED IN 1 VOL. 8VO.)

Notice on the «École des Ponts et Chaussées». Paris, 1873, pamphlet 8vo.

Decree of the 13th October 1851, enacting the organization of the «Corps des Ponts et Chaussées». Paris, 1867, pamphlet 8vo.

Decree of the 13th October 1851, enacting the organization of the «École des Ponts et Chaussées.» Paris, 1867, pamphlet 8vo.

International regulations of the «École des Ponts et Chaussées». Paris, 1875, pamphlet 8vo.

«École des Ponts et Chaussées». — Admission of private students to the courses of lectures. Decrees, orders, decisions, programme of attainments required for admission. Paris, 1878, pamphlet 8vo.

Preparatory courses of lectures for the admission of private students to the «École des Ponts et Chaussées». Decree. Programme of attainments required for admission. Paris, 1878, pamphlet 8vo.

Aucoc. — Administrative authorities. Paris, Dunod, 1878, pamphlet 8vo.

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DARTEIN (DE). — Study on Lombard architecture and the origin of the Roman-Byzantine or Romanesque architecture. Paris, Dunod, 1865-1878; text, 1 vol. 4to.; atlas, 1 vol. folio.

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COLLIGNON (Édouard). — Course on analysis and mechanics de[illegible]liv-ered at the «École des Ponts et Chaussées». Notes taken by the s[illegible]tu-dents. Paris, 1876-1877, 2 vol. 4to. lithographed.

GARIEL. — Course on physics delivered at the «École des Pont[illegible]s et Chaussées». Notes taken by the students. Paris, 1876, 1 vol. 4[illegible]to. lithographed.

PILLET. — Course of descriptive geometry and stereotomy deli[illegible]v-ered at the «École des Ponts et Chaussées». Notes taken by the st[illegible]u-dents. Paris, 1876, 1 vol. 4to. lithographed.

DURAND-CLAYE. — Course on chemistry delivered at the «École d[illegible]s Ponts et Chaussées». Notes taken by the students. Paris, 1878, 1 vo[illegible]. 4to. lithographed.

LALANNE. — Exposition of two methods of abridging calculation[illegible]s for earthworks. Paris, Dunod, 1879, 1 vol. 8vo.

LALANNE. — Collection of graphic methods and tables. Pamphlet, [illegible] 4to.

6° VARIOUS WORKS.

SGANZIN, REIBELL and LALANNE. — Programme of the lectures of a [illegible] course on construction. 1st part. Paris, Dunod, 1865-1867; text, [illegible] 1 vol. 4to.; plates, 1 vol. folio.

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1st part. The flow of water in open channels.
2nd part. Experimental researches into the propagation of waves. Paris, Dunod, 1866; text and plates, 2 vol. 4to.

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BELGRAND. — The Seine. System of rains, springs, running waters, nd their application to agriculture. Paris, Dunod, 1873; text, 1 vol. vo.; plates, 1 vol. folio.

BELGRAND. — Water. Introduction, the Roman aqueducts. Paris, nod, 1875; text, 1 vol. 8vo.; atlas, 1 vol. folio.

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XXXVIII

GRAPHIC METHODS

FOR

THE EXPRESSION OF EMPIRICAL OR MATHEMATICAL LAWS

WITH THREE VARIABLES,

WITH THEIR APPLICATION TO ENGINEERING

AND TO THE SOLUTION OF NUMERICAL EQUATIONS OF ANY DEGREE,

By M. Léon LALANNE,

Inspector general «des Ponts et Chaussées», Director of the «École»,
Member of the Academy of Sciences.

Preliminary statement. — The following notice is, for the most part, the reproduction of that which appeared in a publication on the works of the « Ponts et Chaussées » and was compiled by the Ministry of Public Works, on the occasion of the Paris Universal Exhibition in 1878. Two years having elapsed since that time, it was natural that the author should revise his work carefully. In accomplishing this revision, he has endeavoured to render it more complete, and has corrected a few inaccuracies which had previously escaped his observation.

Plan and object of this notice. — The graphic methods, the principal results of which will be shown in this paper, took their origin and development in the requirements of the various services which demanded on the part

f the engineers and agents « des Ponts et Chaussées » the mployment of expeditious means for making calculations, ometimes wearisome, and always involving the consumption f much time. A brief explanation of the circumstances that ave rise to the new ideas, will make apparent the tardiness f conception, also the hesitations and errors that have been ommitted, and that a purely didactic exposition would ave concealed. But the beneficial results accruing to the hilosophy of science, from an attentive observation and a eracious description of the manner in which ideas are ori- nated and succeed each other, largely preponderate over nsiderations of the « amour-propre » peculiar to authors.

Origin of the employment of graphic methods r calculations appertaining to the preparation of lans and specifications. — In 1834, the author of is notice was nominated to a service which involved the most immediate formation of new roads, and consequently e rapid preparation of plans, especially estimates of earth- orks to be made, and superficies to be appropriated to ublic purposes. By a process of generalization, he had com- enced to avail himself (1835) of the methods conceived, id already successfully employed by M. Fourier, engineer chief, at the period of the formation of strategic routes.

The late M. Coriolis, member of the Academy of Sciences, ad applied himself, simultaneously, to the consideration of ie same subject, and the numerical tables calculated by im in Paris, were addressed to the engineers of the depart- nents on the 18th January 1836 and the 24th August 1837.

Nevertheless it appeared desirable that a method should

be discovered, which, even at the cost of extending the calculations, might be applicable to questions not foreseen in the tables, the scope of which was necessarily limited, while they had been compiled for plans the dimensions of which were determined. The author of this notice submitted a solution of this kind to the inspection of M. Coriolis, and in accordance with the advice of that revered scholar, the Administration caused the volume to be distributed to all the engineers, accompanied by an explanatory circular dated the 27th March 1840. It was entitled *Tables nouvelles pour abréger divers calculs relatifs aux projets de routes*, Paris, Royal Press, February 1839, 8vo. (See *Annales des Ponts et Chaussées, Laws and Ordinances of 1840.*)

In this publication will be found the first enunciation of the idea of a graphic representation, relative to the numbers required to be calculated, and to the tables in which they can be arranged after obtaining them. In the case most frequently recurring, that of a road with lateral drains, these depend on not less than nine systems of formulas, of which four are by far the most frequently employed, and correspond to a transversal section either of a cutting or of an embankment. The five others are determined by certain conditions of inequality between the data of the transversal section, in which a cutting and an embankment are found at the same time. But the preliminary operation, which consists in discovering which of the nine systems should be employed, may be facilitated by a graphic construction which naturally presents itself to the mind. It will be observed in the first place, that for a definite outline of transversal section, the calculation only depends on the

altitude number on the axis, and on the transversal declivity commencing from the axis; so that considering the transversal declivities as positive abscissas, when they are in inclined plane, and as negatives when they are in slope, calculating in the same manner, the altitude numbers of the cutting on the positive ordinates, and the altitude numbers of the embankment on the negative ordinates, all possible cases correspond to the points comprised in the interior of a rectangle, the dimensions of which are determined by the extreme values admitted for the transversal declivities, and for the cutting or embankment at the axis.

Now, into the inequalities that limit the use of the various systems of formulas, the declivities and sides only enter to the first degree. The spaces that comprise the ensemble of the points, the coordinates of which altitude (number and declivity) correspond to one of the nine systems of formulas, are thus limited by straight lines.

This will become manifest from the inspection alone of figure 1. The total rectangle MNOS is divided into four equal rectangles corresponding, viz.

OAMB	to ground in inclined plane ($x = c$) and	cutting $y - d$.
OASB′	to a side in	embankment $-y - r$.
OA′NB	to ground in slope $-x = p$ and to side in	cutting $y - d$.
O′AQB′		embankment $-y - r$.

With the exception of the first example, which admits of only one formula, because the superficies of the cross half-section is then entirely in cutting, each of the others subdivides itself; and the numbers from 1 to 9 indicate what triangular or trapezoidal spaces are occupied on the figure, by the ensemble of the points of which the coordinates cor-

respond to the systems of formulas bearing the same num bers.

A first consequence, which is not devoid of interest, co

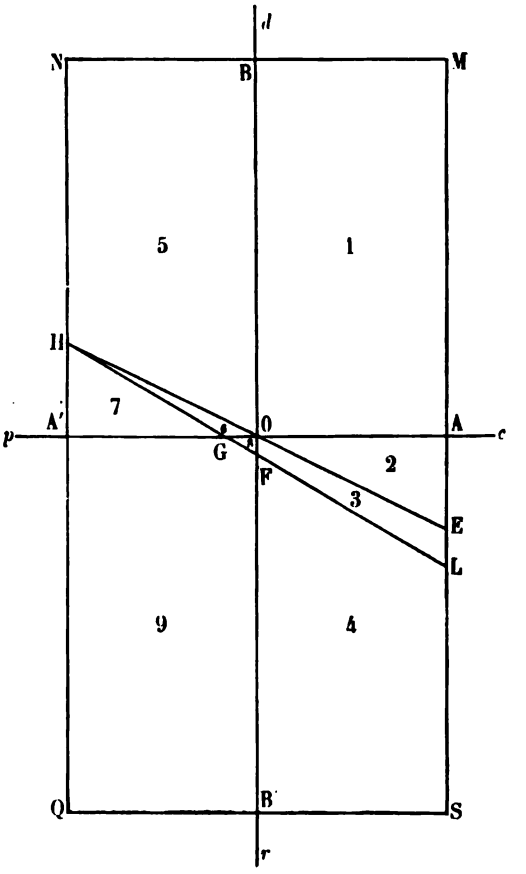


Fig. 1. — Graphic representation of the spaces corresponding to the nine syste of formulas to be employed in calculations relating to plans of roads.

sists in the fact that numbers of examples, to which various systems of formulas are applicable, are proportic to the superficies of these rectangular, triangular or tra

ıl spaces; so that the relations of two of these superfi-
express, *a priori*, the respective probabilities of the
loyment of such and such a system of formulas, other
litions being equal.

irst application of this kind. — It was perfectly
ral that this figure should be utilized for the purpose of
ing at a new geometrical expression of the values ob-
ed by means of the formulas. It was only necessary to
gine at each point of the supposed horizontal plane, a
endicular proportional to the superficies of the cutting
mbankment corresponding to the two coordinates of this
t, and that a continuous curved surface passes through
extremities of these perpendiculars. This idea, appa-
ly so simple, did not appear in the work of 1839, al-
ıgh it was nearly approached in that publication. (See
: 14 of the *Instruction* preceding the *Tables Nouvelles*.)
: only appeared at the date of a publication issued at
request of Reibell, the eminent engineer to whom we are
ebted for the fourth edition of the *Programme* ou *Résumé*
Cours de construction by Sganzin. That work contains the
methods of calculation for the preparation of plans
oads, summarized and accompanied by numerical tables
ın abridged form (1842), and in the appendix will be
ıd a lucid exposition of the construction of curved sur-
:s of this description, above the plane of horizontal pro-
ion figured in the preceding diagram; there is also set
h the advantage offered by the draught of projections of
level curves of these surfaces, for the determination of
ues of vertical ordinates to be calculated in each parti-

cular example. Figure 2 is only the rectangle OAMB of figure 1, enlarged, in the interior of which have been drawn from 10 to 10 level parabolic lines of the curved surface, corresponding to an definite outline with a plat-

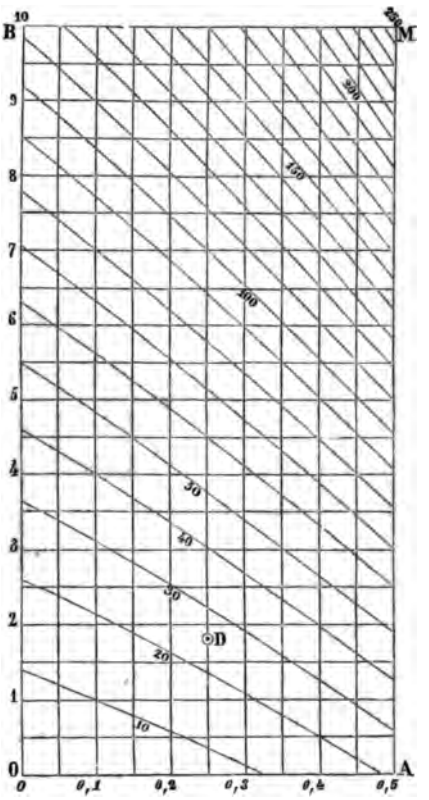


Fig. 2. — Graphic representation of the numerical results given by the first of the nine systems of formulas of the preceding figure.

form 10 metres in breadth, the vertical ordinates of which represent the values of the superficies of cutting; these lines of level are comprised in the equation

$$z = \frac{(6^m,50+y)^2}{2(1-x)} - 20,625,$$

ıen z is varied successively from 1 o to 1 o starting from o 25o. If by means of this figure, we desire to find the value of the superficies of a half-profile in cutting, for a road) metres broad between the ditches, the transversal de-ivity x taken for abscissa, being $0^m,25o$ in inclined plane, ıd the altitude number on the axis y taken for ordinate, eing $1^m,8o$ in cutting, the point D (surrounded by a small rcle), which is determined by these two coordinates on ıe figure, evidently falls in the middle of the interval be-veen the curves numbered 2o and 3o; we therefore obtain 5 as the corresponding value of z, of the vertical ordinate, ıd the required superficies of the cutting is, approxi-atively, 25 square metres. The exact calculation gives),3o square metres.

General principle of the graphic expression of double entry numerical table; former examples nown. — The method previously adopted for replacing double entry numerical table, the results of which depend pon a formula with two independent variables, was evi-ently applicable to all laws into the expression of which ıree variable elements enter. This stage in the development f the theory was passed on the day when it was enunciated ıat a law of this kind, whether natural, empirical or mathe-ıatical, can be represented by a surface, and consequently y a topographic plane with numbered curves of level.

In the *Appendice à la Météorologie de Kaemtz*, translated nd annotated by Ch. Martins, the author of this notice ;ave, for the first time, a general exposition of this order of deas, with their special application to the laws of meteo-

rology (1843). The volume is accompanied by four plates, which include a great number of examples of these topographic planes, and figures with curves of equal elements. The most remarkable one which has been frequently reproduced, and which we have constructed first, appears in this place as N° 3. It expresses the law of the temperatures observed at Halle, by Kaemtz, for each hour of the day (ordinates) and each month of the year (abscissas). The ridge and water-course lines, the summits and depressions here presented, together with the contrast afforded by the effect of the uneven ground, impart to it a resemblance which forcibly strikes those who view it for the first time. The author will never forget the earnest and kind persistence, by means of which the illustrious Élie de Beau-

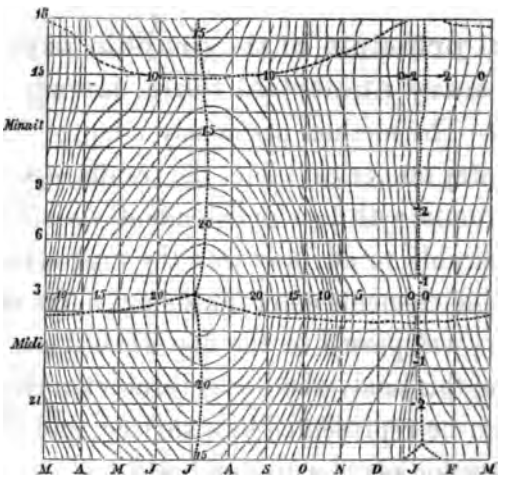


Fig. 3. — Graphic representation of the monthly and hourly variations of temperature at Halle, according to Kaemtz.

mont succeeded in inducing him to make this application of numbered planes the subject of a communication to the Aca-

lemy of Sciences. He desired that the expressive notation should be promulgated, so that in a great number of cases, it might furnish views of the ensemble which tables of figures cannot give, even when they offer all their elements[1].

In fact, at this period, if there actually existed a few cases in which laws of three variables had been represented by curves of equal value, the authors of the greater part of these isolated examples do not appear to have associated them with any general order of ideas. The properties of planes with numbered lines of level, continued to be studied with reference only to the expression of the relief or inequalities of the surface, and if lines of equal elements were employed in the place of a double entry numerical table, it was, in almost every case, without appearing to imagine that they represent surfaces existing in space, the relief of which proceeds from the aspect of the numbered plane.

This is the case with the *Arithmétique linéaire* inserted by Pouchet 1795 in the second edition of his work entitled *Échelles graphiques des nouveaux poids, mesures et monnaies de la République française*, Rouen and Paris, year IV of the Republic, 8 vo. In this work is seen, for the first time, a double entry graphic table employed concurrently with the compass, for the purpose of effecting operations of multiplication and division. In a new edition, entitled *Métrologie Terrestre* (Rouen 1797), this table is modified so as to dispense with the use of the compass.

[1] In my appendix to the translation of the *Meterology* of Kaemtz, the part of the text which relates to this figure, contains some errors in respect of finding averages, which I have unfortunately confounded with the ordinates of centres of gravity.

At a much later date, in 1840, a clever naval engineer, M. Allix, likewise published a *Nouveau système de tarifs* (Bachelier, 8 vo.) in which the graphic tables can be used without calculation and without employing any instrument, and give the weight of metals in bars and sheets, the cube of rough or squared timber, the cube of squared stone etc., etc. The lines of equal length, in these tables, were in no way connected with the surfaces of which they are the implicit representation.

The name of Obenheim, an officer of engineers and professor at the «École d'Artillerie at Strasbourg», takes its place between those of Pouchet and Allix. In his *Balistique* (Strasbourg, 1814) and in his *Mémoire sur la planchette du canonnier* (Strasbourg, 1818), this learned man explicitly indicates the construction of curves of equal value; but neither does he carry it back to the idea of horizontal sections of surfaces.

It was only in N° 3 of the *Mémorial d'Artillerie*, published in 1830, that in a review of the works of Obenheim, M. Terquem, the learned librarian of the Central Depot of Artillery, distinctly enunciated this idea (page 297). In the same volume, he mentions a graphic construction of the tables of Lombard, suggested by M. Bellencontre, major of artillery, and in returning to the subject (page 376), he shows that a formula which contains three variables representing a surface in space, the numbered horizontal projections of the equidistant sections formed in the surface parallel to the horizon, would give, by readings at sight, the same results as a double entry numerical table.

Whatever may be the share of priority appertaining to

the authors just quoted, Pouchet, d'Obenheim, Bellencontre, Terquem and Allix, it is certain that the use of the graphic methods was scarcely known, and was only applied in a few cases, until the period when these methods were laid before the Academy of Sciences, after forming the subject of a very favourable report (11th September 1843) made by a commission composed of MM. Élie de Beaumont, Lamé and Cauchy, secretary (Reports, vol. XVII, page 492).

New principle of the graduation of the coordinates; geometrical anamorphosis. — It is however not probable, that the use of the graphic tables with curves of equal value, would have been widely extended at any time. The construction of these tables occupies much time, and is attended with much trouble; the readings also are impeded by the difficulty of following the same curve, unless the numbers are considerably multiplied. A more profound investigation was soon applied to elaborate a system of construction possessing none of these disadvantages.

The author who believes he has discovered a new idea, is almost always actuated by a desire to give it the widest extension, and endeavours to apply it to the greatest possible number of examples. In consequence of this psychological tendency, an endeavour was made to convert a double entry table of logarithms of the same description as those of Callet into a graphic table with lines of equal number, and it was soon apparent that, the sum of the coordinates of all the points of a right line equally inclined on the axes being constant, it was sufficient to calculate on these axes the proportional lengths, not to the numerical values, but to the logarithms of

the coordinates, in order that the geometrical position of all the points of the plane, of which the product of the distances is constant, should become a right line. With the axes of the coordinates graduated in equal parts, the succession of the equilateral hyperbolas was obtained, in which the *power* varies as in natural numbers; this was Pouchet's table. By replacing the equal divisions by a logarithmic graduation, the lines of equal product numbered 1, 2, 3, 4, become right lines inclined to 45° on the axes. The hyperbolas have thus been transformed into other lines by means of the use of *graduated coordinates* following a determinate law; and this kind of transformation may be denominated *geometrical anamorphosis.*

The table known since 1843, and which we have designated under the name of *Abaque ou Compteur universel*, is the anamorphosis of the table of Pouchet. It consists mainly of three pencils of right lines, viz. *verticals* corresponding to abscissas, *horizontals* to ordinates, and *obliques*, the number of which expresses the product of the abscissa by the ordinate.

The principle of graduation of the coordinates consists in the fact that, if, in an equation of three variables, the separation of the variables can be effected by substituting for them certain functions of each, then the graduation of the axes of the coordinates, effected according to the law which the functions express, will give rise to an anamorphosis, and will reduce to more simple lines, the sections determined on the surface by the horizontal planes. The equation of the pr-

then

$$x' = \log x, \quad y' = \log y, \quad z' = \log z,$$

and there results

$$x' + y' = z'.$$

The parallel right lines that the anamorphosis has substituted for the hyperbolas comprised between the same asymptotes, might, in their turn, be replaced by concentric circumferences, for it would suffice to place

$$x' = x''^2, \quad y' = y''^2, \quad z' = z''^2$$

in order that the proposed change should be to

$$x''^2 + y''^2 = z''^2;$$

in this case, the graduation of the coordinates is effected according to the square roots of the logarithms of the numbers.

First application to projects of railways and roads. — Such are the principles[1] that constitute the base of the solution of the problem, which at that time engrossed the attention of the Ministry of Public Works. The law of the 11th June 1842 had decided the establishment of the first system (réseau) of railways, which was required to be exe-

[1] These principles and their application were expounded in the Notice of which the Academy authorized the insertion in the Recueil des Savants Étrangers, and which appeared in a more developed form, in the Annales des Ponts et Chaussées (1st half year 1846) under the title *Mémoire sur les tables Graphiques et sur la géométrie anamorphique.* The suffrage of the engineers awarded a gold medal to this Notice (Annales, 2nd half year 1847, p. 378).

cuted with promptitude, and expeditious methods were needed for estimates of the earthworks peculiar to undertakings of this nature. Stimulated by circumstances analogous to those which had occurred in 1834, at the time of opening the departmental roads of La Manche, the author had succeeded in reducing to a degree of unexpected simplicity calculations which would have demanded the employment of numerical tables not in existence, and the compilation of which would have necessitated a considerable outlay. With a circular dated the 2nd September 1843, the under-secretary of State for Public Works addressed to all the prefects and engineers two sheets of graphic tables relating to railways with two lines (*Annales, laws and ordinances*, 1843, p. 676). Tables of the same kind for projects of district lines, 6 metres broad, were also sent to the prefects and road trustees (circular N° 50, 1843).

This system of graphic tables, comprising only 3 courses of right lines intersecting each other (horizontal, vertical and oblique), has been applied by the author at different periods, to railways projected with one or two lines of rails in the centre of France, from 1844 to 1846, and quite recently (in 1877) by M. Ricour, engineer in chief, to the various lines the execution of which was confided to him by the State.

The new model of tables owes its origin to circumstances of a peculiar nature. The late M. Davaine, an engineer of great merit, had invented and published in 1845, in the *Mémoires de la Société des sciences de Lille*, a graphic table of great originality, for the simultaneous determination of all the elements in question. The employment of a series of

curved lines of a difficult character, was necessary for this table, to which a generality had been attributed which it did not really possess. The anamorphosis of the figure, effected by the application of the principle of graduation of the coordinates, transformed the curves into parallel right lines and showed four courses of right lines intersecting each other at 45°, the ensemble of which is nothing more than a fragment of the primitive Abacus, completed by the pencil of transversals perpendicular to the obliques. Now the simultaneous employment of these transversals and of three other courses of right lines, allows the squares to be operated upon as easily as the numbers themselves, and particularly to obtain by a single reading, the quotient of the square of one number by another, and this is precisely what is required in estimating the superficies of a cutting or embankment in a cross section. The courteous discussion that ensued, in consequence of the publication of the treatise of M. Davaine, was not entirely lost, since it originated some interesting variations in the establishment of graphic tables[1].

[1] See on this subject the paper entitled : *Examen critique d'un tableau graphique publié par M. Davaine, et nouvelles applications de la géométrie anamorphique* (Annales des Ponts et Chaussées, 1st half year 1850, p. 133). M. Lalanne had made an appeal to the judgment of M. Davaine, on the subject of certain passages in the Lille publication, and the latter gentleman replied with a frankness and kind feeling worthy of all praise : « I trust », said he, « that M. Lalanne will be willing to recognize in the date of that paper a sufficient excuse for the assertions he recalls to my recollection. At that time I had no knowledge of the excellent papers he has since published; but even then, if I had been called upon to give my ideas upon the merits of his works, he would have found in my opinions, only a sincere expression of the highest esteem, added to the desire that he should have all the honour of his researches. » (Annales des Ponts et Chaussées, *ibid.*, p. 174.)

Among the tables of this system, the first in date is that of which the manuscript was presented by the author to the library of the « École des Ponts et Chaussées »; it is entitled: *Notice sur les procédés de calcul employés par les ingénieurs anglais pour la rédaction des projets de chemins de fer, avec un tableau graphique destiné à remplacer et à compléter ces tables* (1851). Shortly afterwards, on the resumption of works consequent upon a new political regime, the Northern and Eastern Railway Companies were in haste to construct various lines not included in the primitive concessions. The execution of these projects was compulsory, on the Northern, by the decree of the 19th February 1852, on the Eastern by the decree of the 17th August 1853, and they requested the author to furnish them with new methods for the compilation of tables adapted to their special models. These tables were prepared and engraved in 1852 and 1854, according to the new system, which unites on the same plate the superficies of cutting and embankment, the lengths of the lands required, the lengths of the talus, for the sides of the cuttings or embankments, up to 20 metres, and for the slopes of the natural surface rising to $0^{m},500$.

Tables of the same description were used in preparing the project of the Western system (réseau) of Swiss railways, the direction of which was confided to the author of this paper (1856).

More recently still, when the extraordinary impulse given to public works decided the undertaking of surveys for the construction of new railways, throughout the extent of French territory, the higher authorities gave a cordial reception to the author's proposition with respect to the ana-

morphic method of calculating, with new tables adapted to the various outlines of transversal sections in which variations occur in the breadth of the platform and the slope of the talus of excavation. Eight of these tables were engraved and sent to all the engineers, to whose attention they were specially recommended by a ministerial circular of the 30th July 1879. « I have felt the less hesitation in ordering their execution, » said the Minister, M. DE FREYCINET, « inasmuch as the use of the graphic methods, as a means of calculation, is every day becoming more widely diffused in France as well as abroad, and the opinion of the General Council « des Ponts et Chaussées » amply corroborates the verdict of the jury of the Universal Exhibition for class 66, by virtue of which verdict, the highest recompense, the diploma of honour, was awarded in the special Exhibition of the Ministry of Public Works, to the collection of graphic methods of which the new tables are an application. »

At the time when this Notice is going to press, the author has just completed four tables of the same description for the Corsican railways, of which the outlines of transversal sections are much narrower than those used for the Government railways on the Continent.

Cost price of the Tables. Saving of time effected. — The cost of the tables engraved in 1843, amounted to 1 309 francs for 1 000 copies, or 1f,31 for a complete copy of a total superficies of 1,05 square metre, inclusive of 300 francs for expenses of calculation.

The tables give the areas in cutting and embankment, in the cross sections and the breadths of the lands required

for the numbers up to 10 metres on the axis. M. Ricour, engineer in chief, has established on four plates $0^{m},70$ by $0^{m},30$, as many tables as show the superficies of cutting, and embankment, the breadths of the lands required, the lengths of the talus for the altitude numbers on the axis, up to 20 metres, and for the declivities of the transversal section, up to 0,40.

The transfer on stone and the printing of 200 copies cost 124 francs, paper included, or $0^{f},62$ for each collection of four tables having a total superficies of about 0,84 square metre. The compilation of each table occupied fourteen hours for the calculations and twenty-eight hours for the drawings.

As before-mentioned, these expenses apply to tables calculated on the primitive system which gives separately the surfaces, the ground taken, and the talus. With regard to tables of the latest model, which show these three elements simultaneously, by means of two data of the question, we have succeeded in obtaining three thousand copies for $3\,464^{f}$ a collection of 8 tables, which brings the price of a set to $1^{f},55$ and the price of a single table to $0^{f},144$. The expens of calculation, and the drawings which serve as a model t the autographers and engravers, are not included in th preceding figures, which only descend so low, on accour of the great number of copies demanded for the require ments of the service, at the time of the distribution by th Government. On the other hand, the hundred copies of th tables for the two special sections for Corsica, cost not le than 553^{f} or $0^{f},691$ for each of the four engraved tabl composing the collection applicable to two different model

A considerable saving of time is effected by the use of the graphic tables, especially as the drawings of cross sections may be dispensed with. In the system of the tables of 1843, it follows from the experience of M. Ricour, that two minutes suffice for reading the three numbers sought, area, ground taken and talus, and that the error rarely exceeds 1 per cent.

With the new system, in which the reading of these three quantities is effected on one table instead of two, the time employed in operations is still further abridged. In practice, a notable advantage would be gained by having the data of the question read aloud by an « employé » who would afterwards write, to the dictation of the operator, the figures corresponding to these data.

Special use and properties of the Abacus[1] with transversals. — By this example, it will be seen that a certain length is required in the projected plan, in order to resolve on establishing the engraved tables. On the other hand, the number of designs might be considerable, in the case where the nature of the ground caused variations in the breadth of the platform and in the declivities of the talus, and it would scarcely be expedient to compile and print tables that would only be applicable to a small number of sections.

For these particular cases it will be sufficient to employ the complete Abacus before-mentioned and of which fig. 5 is a reduction to a very small scale. In this figure, the edges of the frame and the diagonals of the square are graduated

[1] The original Latin term *Abacus* is here employed as being obviously preferable to the English words « calculating table. » (*Note by the Translator.*)

according to the logarithms of the numbers inscribed in it. If then the *oblique* MR and the *transversal* MC (fig. 4) are considered separately, it will be seen that, owing to the logarithmic graduations, the number z of the oblique which passes through the point of meeting M of the *perpendicular* PM and the *horizontal* QM, carried respectively to distances ex-

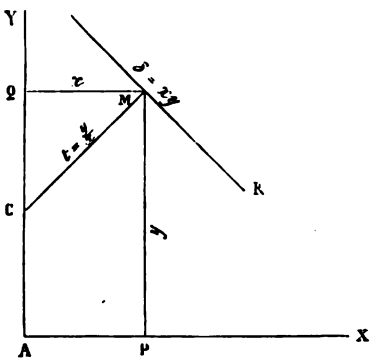


Fig. 4. — Diagram showing the fundamental relations between the values of the four courses of lines of the *Abaque ou Compteur universel.*

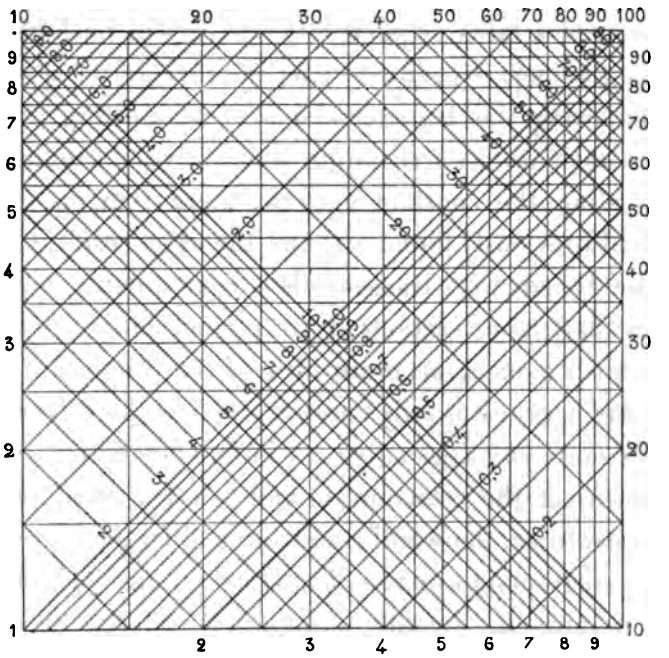
pressed by $AP = x$ and $AQ = y$ coincides numerically wi[illegible] the relation $z = xy$... (1). It will also be seen that t[illegible] number t of the transversal MC, which passes by the sa[illegible] point M, is connected with x and y by the relation $t =$ [illegible] whence results $z = \frac{y^2}{t}$... (2).

Now the areas of cutting or embankment are express[illegible] by the formula

$$S = \frac{(a \pm y')^2}{2(b \mp x')} - c,$$

in which x' designates the declivity of the natural grou[illegible] and y' the altitude number on the axis, a, b and c bei[illegible] constant quantities, relative to the outline adopted. It will

en be sufficient to follow the transversal $2(b \mp x')$ to the int of meeting $a \pm y'$, to read the value z of the first term



5 — Abacus with transversals on which the following results are obtained at sight.

PRODUCTS.	QUOTIENTS.	SQUARE ROOTS.
$z = xy$; $y = lx$	3° $x = \frac{z}{y}$; $l\frac{y}{x}$	6° $y = \sqrt{zl}$
$z = lx^2$	4° $z = \frac{y^2}{l}$	7° $x = \sqrt{\frac{z}{l}}$
	5° $l = \frac{z}{x^2}$	

N. B. — Conformably to the indications of fig. 4, the x are read on the horizon-s, the y on the verticals, the z on the obliques and the t on the transversals.

f S on the oblique, passing through the point of meeting. Eliminating the constant c, we shall have S the superficies

required. In the example previously given for the half-outline $6^m,50$ in breadth, with an altitude number in cutting $1^m,80$ on the axis, a transversal declivity $0,250$ in inclined plane, and a talus regulated to 45°, it will be found that $2(b-x')=2(1-0,250)=1,5$; and that $6,50+y'=8,30$. By following the transversal 1,5 to its meeting with the horizontal 8,30, we arrive approximatively at the oblique 46; eliminating the constant 20,625, there remains 25,375. We had previously found 25, and the exact result is 25,30.

The Abacus with transversals is consequently applicable to calculations of sections of exceptional outlines. In order to furnish a more accurate idea of the properties of this singular figure, it is only necessary to find the values of any two of four quantities x, y, z, t in function with two others by means of the relations (1) and (2). For each of these four quantities, there will result three different expressions, which correspond to seven distinct operations, each of which only requires the reading of a number relative to the two data of the question, viz. : 1° and 2° the product of two factors, one of which may be a square; 3°, 4° and 5° the quotient of two numbers which may both be simple, or one of which, either the dividend or the divisor, may be a square; 6° and 7° the square root either of the product, or of the quotient of two numbers. The simultaneous employment of these fundamental data, with transversals inclined to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$... of base for 1 of height, and which serve to determine integral and fractional powers, leads to a great number of combinations, some of practical utility in calculation, while others can only be regarded in the light of curiosities.

Different uses and models of the Abacus. — In his report, read before the Academy 11th September 1843, M. Cauchy remarks that «M. Lalanne has constructed an Abacus which resolves the various operations of arithmetic with great facility, even the elevation of a number to a fractional power. M. Lalanne's Abacus generally furnishes two or three figures of each of the numbers proposed for calculation[1]».

From the period when the first model of the Abacus (at that time in manuscript) was thus brought into notice by the Commission of the Academy, special applications of it were made and new models constructed. From 1847, M. Alan, the learned professor at the Conservatoire, added to his *Traité des matières textiles* an Abacus adapted to calculations involving the conversion of the ancient titrage, and of the English titrage or volumetric analysis, into metrical titrage. L'*Abaque des équivalents chimiques*, published in 1846, with explanatory details, is one of the numerous applications that may be made of the primitive Abacus (2nd edition, 1854).

The Abacus with transversals (fig. 5), the application of

[1] Since that time, the Abacus has been recommended by the Society of Elementary Instruction (at a meeting held 1st April 1846); by the Society of Encouragement, which awarded a platina medal (Report, vol. XLV, p. 658); it has been authorized by the Council of the University (14th January and 4th April 1848) to be used in the primary schools of different degrees, and recommended by the Minister of Interior to the prefects for the use of road trustees (circular n° 5, 28th January 1847). It was sent by the Minister of Public Works to all the engineers «des Ponts et Chaussées» and «des Mines» (circular n° 1, 24th March 1847). A mural Abacus of large dimensions has been constructed for the use of schools.

which to calculations for cuttings and embankments has just been explained, may be considered as the type of a new and special series, in which powers of different degrees might be combined by means of several series of right lines parallel to each other and separated by logarithmic intervals.

We have shown in addition that the succession of equilateral hyperbolas, represented by the equation $xy=z$, may be anamorphosed at pleasure either in right lines inclined to 45° on the axes, or in concentric circumferences; in the latter case, the graduation of the coordinates is made according to the square roots of the logarithmic values of the graduation in the preceding case.

Application of the anamorphosis to laws of which the mathematical expression is unknown. — The principle of the graduation of the coordinates may be applied, even when the mathematical law according to which it is operated, is not explicitly known; it is only necessary to possess numerical terms sufficiently approximative. In this manner, without determining the form of the function $x=f(a)$, which expresses the number of individuals whose age is at most equal to a number of years a, in a limited population, as soon as the number corresponding to each value of a is found, a table composed of right lines may be constructed, which will give, at sight, the total number of individuals comprised between the two ages a and a'. In fact, the number of those whose age is at most equal to a will be expressed by $x=f(a)$, and the number of those whose age is at most equal to a' by $y=f(a')$, and the number of those whose age is comprised between

and a' is given by $z=y-x$. This last equation represents a succession of parallel right lines corresponding to the successive values of z, provided that the axes of x and y be graduated, not in equal parts, but according to the successive numerical values corresponding to the different ages of the function $f(a)$, the form of which is unknown.

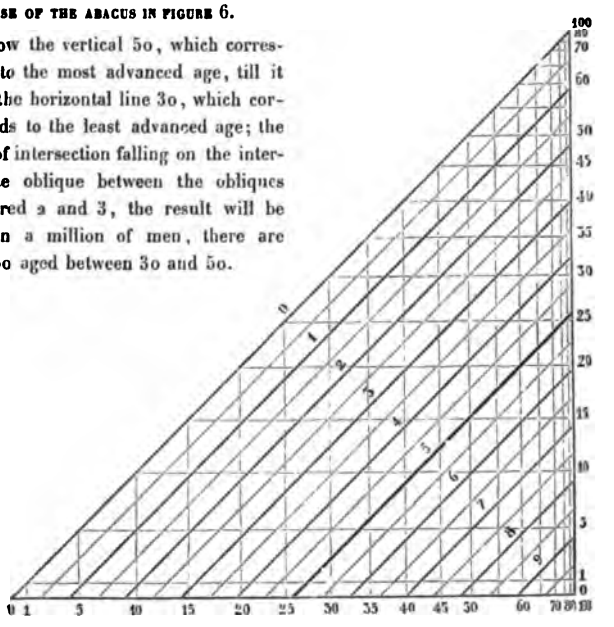

USE OF THE ABACUS IN FIGURE 6.
Follow the vertical 50, which corresponds to the most advanced age, till it meets the horizontal line 30, which corresponds to the least advanced age; the point of intersection falling on the intermediate oblique between the obliques numbered 2 and 3, the result will be that, in a million of men, there are 250 000 aged between 30 and 50.
0 1 2 3 4 5 6 7 8 9
0 1 5 10 15 20 25 30 35 40 45 50 60 70 80 90
100 90 70 60 50 45 40 35 30 25 20 15 10 5 1 0

Fig. 6. — Abacus for calculating at sight the division of the male population according to age.

Figure 6 was constructed according to these principles. Forty-five years ago, the researches of Demonferrand enabled him to classify according to age, the population of France, which comprised nearly 33 millions of souls (*Journal de l'École polytechnique*, 26th number). It was easy for us to deduce from this paper the division, by age, of a population

of a million inhabitants of the male sex. The two sides of the right-angled triangle of the figure are graduated according to the lengths proportional to the numbers of individuals of each age, and the parallels to the hypotenuse are made equidistant and numbered from 1 to 10, each corresponding to a number of hundreds of thousands of souls indicated by the number. To find, from this figure, the number of men between 20 and 40 years, the limits of the age for military service, the vertical 40 must be followed till it meets the horizontal numbered 20. The point of meeting being nearly on the oblique numbered 3, it follows that, in a million of male inhabitants, there are 300 000 between 20 and 40 years; and consequently that, according to the last census which returned the population as numbering 36 000 000 of souls, the two axes being nearly equal in number, there are nearly 5 400 000 men simultaneously fit for military service.

The double anamorphosis. — The three figures 7, 7 *bis* and 7 *ter* show in different ways, at each age, the probabilities of living to a determinate age; the comparison is to a certain extent interesting from a natural point of view as well as from the diversity of the effects of the anamorphosis. It is still a question of a natural law the mathematical expression of which is not ascertained, but the numerical terms are known, if we admit the law of mortality laid down by Demonferrand for all France, without distinction of sex. The curves of figure 7 show, by their numbers, for all the points in the interior of the triangle, of which the coordinates correspond to two determinate ages,

the probability there is for the mass of individuals of age a to attain the age a'.

Figure 7 *bis* is the *simple anamorphosis* of the figure 7, determined by a consideration analogous to that by means of which figure 6 was constructed. In fact, if the numbers x and y of individuals, aged respectively a and a' years, who

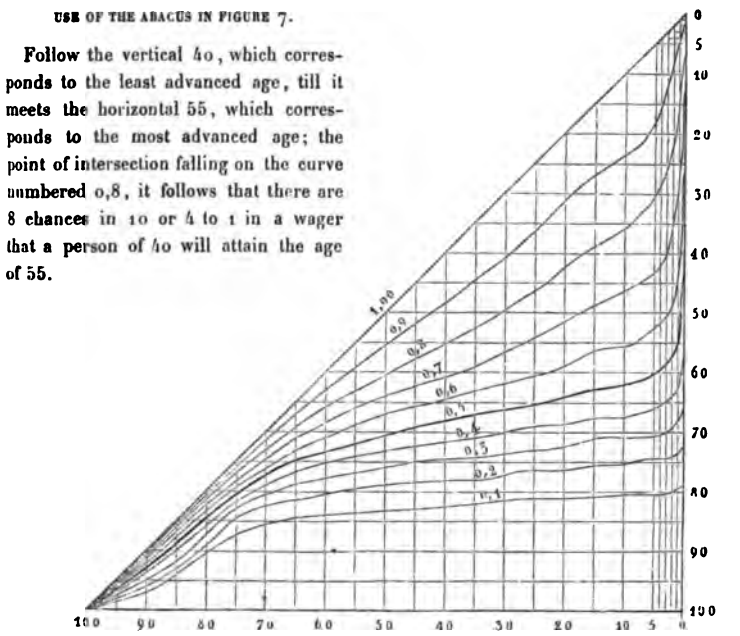

USE OF THE ABACUS IN FIGURE 7.
Follow the vertical 40, which corresponds to the least advanced age, till it meets the horizontal 55, which corresponds to the most advanced age; the point of intersection falling on the curve numbered 0,8, it follows that there are 8 chances in 10 or 4 to 1 in a wager that a person of 40 will attain the age of 55.
1,00
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
5
10
20
30
40
50
60
70
80
90
100
100 90 80 70 60 50 40 30 20 10 5 0

Fig. 7. — Abacus (without anamorphosis) showing the probabilities of life at each age for the average of all France, without distinction of sex.

survive in 10 000 born on the same day, the probability z of attaining the age a' will be expressed by the fraction $\frac{y}{x}$ for those who have attained the age a. This variable probability will be represented graphically by the pencil of diverging lines, the equation of which is

when increasing values are successively given to z, for example from tenth to tenth, from 0,1 to 1. In this construction, it is supposed that the two sides of the triangle are graduated according to the numbers $f(a)$ corresponding to each age.

But when it is a question of inquiries relative to advanced ages, figure 7 *bis* as well as figure 7 presents an abso-

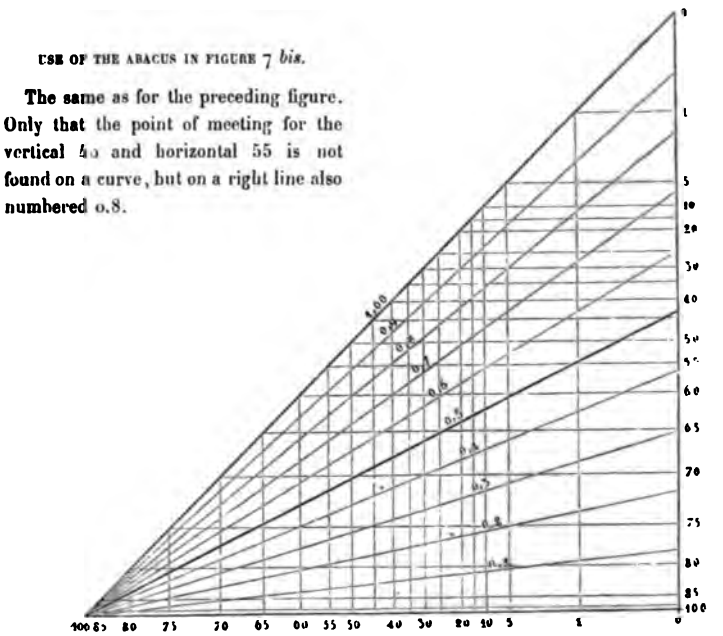

USE OF THE ABACUS IN FIGURE 7 bis.
The same as for the preceding figure. Only that the point of meeting for the vertical 45 and horizontal 55 is not found on a curve, but on a right line also numbered 0.8.

Fig. 7 *bis*. — Abacus of figure 7 after simple anamorphosis.

lute confusion, and it was expedient to transform it in such a manner as to avoid this inconvenience. This end is attained in the construction of figure 7 *ter*, which is the logarithmic anamorphosis of figure 7 *bis*, and which may thus be considered as derived from figure 7 by a double ana-

iorphosis, however it may be obtained directly. In effect, we designate by accented letters the logarithms of the uantities designated by the same letters, we can extract om the equation (3) :

$$(4) \qquad y = x' + z'.$$

low this second equation represents a succession of right

USE OF THE ABACUS IN FIGURE 7 *ter*.

The same as for the two preceding figures and leads to the same probability 0,8 that a person 40 years old will live till to the age of 55. Only the vertical 55 is to be followed to the point of meeting of the horizontal 40. The clearest part of figure 7 *ter* corresponds to the least distinct part of figure 7 *bis* and reciprocally, so that each of these two figures supplies the place of the other with advantage.

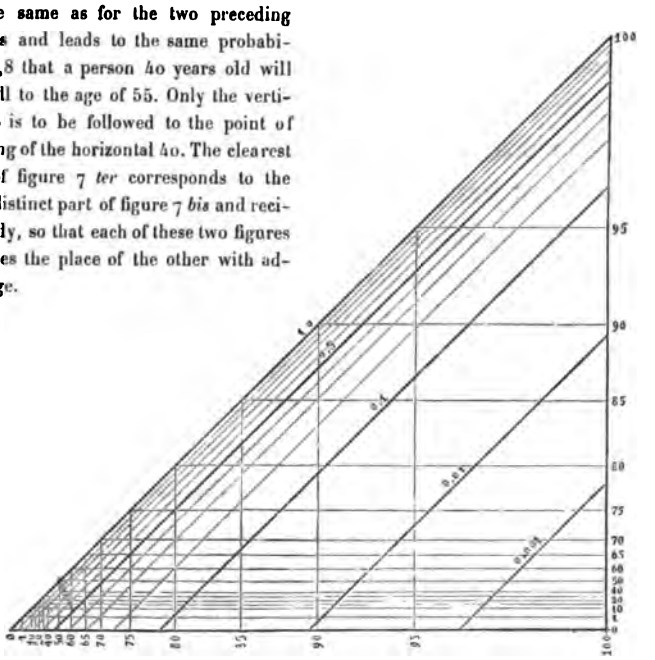


Fig. 7 *ter*. — Abacus of the figure 7 after a logarithmic anamorphosis.

lines, no longer proceeding from the same origin, but parallel to each other, inclined to 45° on the axes of the coordinates, and separated from each other by intervals proportional to the logarithms of the numbers from 1 to 10. The sides of the triangles are graduated according to the numbers

no longer proportional to the numbers of the individuals surviving each age, but to the logarithms of these numbers. In addition to which, figure 7 *ter* presents, for the first age, an inconvenience similar to that which occurred for the last years of life in figure 7 *bis*. In order to find the probability that a person of 25 will live to the age of 65, with any one of the last figures, it is necessary to find the point, the coordinates of which are 25 and 65, and this point falls nearly on the curve or oblique numbered 0,5. In other words, only half the individuals aged 25 will attain the age of 65 years.

Some examples of the application of the notation of the numbered planes. — The publicity given to the new methods has multiplied their application, though all the advantages anticipated have not yet been derived from them. Amongst those which do not relate to anamorphosis, we shall first cite the applications exhibited by the Observatory of the Infante Don Luis, at Lisbon, during the International Geographical Congress in 1875, for showing, according to times and seasons, the variations of temperature, atmospheric pressure, moisture, the velocity of the wind, and terrestrial magnetism, according to the system in figure 3. We may be permitted to recall the fact that the notation of the *wind-card*, traced by the aid of lengths proportional to the duration of the winds that blow in the different rhumbs, and which are now figured on a great number of hydrographic and meteorological plans, in designs relating to maritime works etc., was applied for the first time to the *thermometric or barometric card* in the Appendix to the translation of the *Meteorologie de Kœmtz*, already cited

(fig. 17 and 31 *bis* of this Appendix). In the German original, a notation much less expressive is employed, and is due to Mahlmann the meteorologist (*Abriss einer Geschichte der neueren Fortschritte der Meteorologie*, Berlin, 1833).

It may be added that the rectilinear Abacus is employed by M. Plassiard to express the relations existing between the sound given by a vibrating string, the weight of the unit of length of this string, and the tension to which it is submitted (Congress at Lille, page 192 and pl. II); that the Abacus, also rectilinear, by which M. Thoyot determined the minimum number of brakes necessary for a railway train, given the number of carriages and the rate of speed (Annales des Ponts et Chaussées, 2nd half-year 1874) is an application of the notation of the numbered planes, without anamorphosis.

As far back as the 17th February 1845, the author of this notice had submitted to the Academy of Sciences the plan of a chart on which the division of the population by numbered *curves of equal specific population* should be expressed (Reports, vol. XX, p. 438), the numbers indicating the number of inhabitants per square kilometre throughout the whole extent of the lines to which they apply. « Similarly to a topographical plan, said he, « this chart would present the undulations, steep heights, craters, necks and valleys..... »

Twenty years later, this idea was carried out in the most felicitous manner by M. Vauthier, engineer, who presented to the Academy, on the 26th January 1874, the chart of curves of equal specific population in the extent of the city of Paris, and remarked that it offered analogies to a chart purely topographic. « Heights are seen », said he, « where the population is considerable; levels or plains where it is small;

water-courses are hollowed out in the valleys; promontories are seen with their lines of ridge, etc. » The experiments carried out by a learned and diligent engineer, afford the most ample corroboration of the previsions uttered nearly twenty-nine years before [1].

The movement of the tides is one of the phenomena to which the notation of numbered planes may be applied with the greatest success. The direct observation gives the height of the tide at a given point of the coast, for each day in the year, and each hour in the day. Hitherto, only the results of the observations for each day have been shown, by raising on equidistant abscissas, corresponding to the hours, ordinates proportional to the observed variations of level, and afterwards joining the extremities of these ordinates by a continuous line. This method of operation is the more natural, inasmuch as it adapts itself to the mechanical registration realized by the tide-gauge (*marégraphe*) of Chazallon. Nevertheless it does not give the entire view, unless we obtain from it a disposition similar to that of our fig. 3, viz. a plane with lines of level numbered, taking the hours of the day for abscissas, the days of the month for ordinates, and projecting on it the curves which join continuously all the points corresponding to the exact instants of an equal height of the tide. This disposition was carried out from 1845 by the aid of sinusoidal curves of the tide, drawn from observations made in the tower of Cordouan, and in accordance with our recommendation, it was again applied

[1] In his explanatory notice on statistical charts in relief (Chaix et C^ie^, May 1878, 8vo), M. Vauthier has recognized our priority in this matter with all the frankness and probity which characterize him so strongly.

to the representation of the tides at Brest, and published in the 2nd half-year of the *Annales des Ponts et Chaussées*, 1869 (page 170 and pl. CCI)[1]. M. Quinette de Rochemont, engineer, was also requested to employ this method in order to express the law of tidal movements at Le Havre, during the month of September 1877. Fig. 8 is a reduction of the

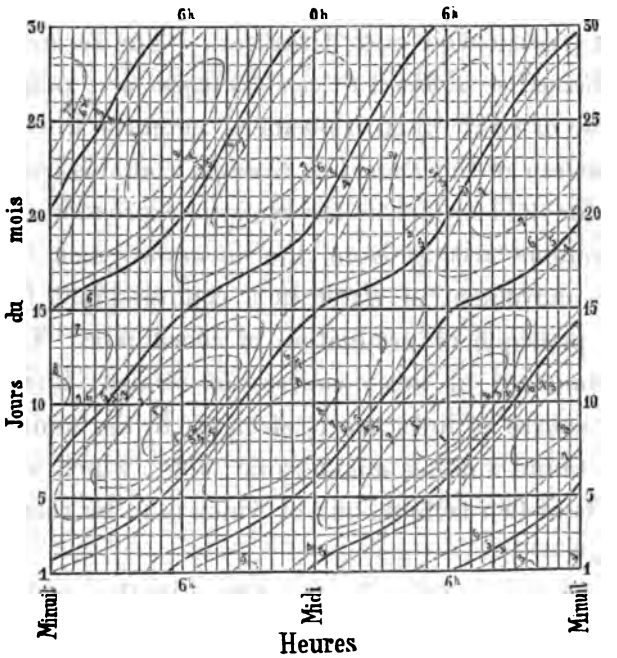


Fig. 8. — Graphic expression of the movement of the tides in the port of Le Havre during the month of Septembre 1877.

draught prepared by M. Quinette de Rochemont, and its advantages will become evident upon examination. A single

[1] In the plate CCI of the volume of the *Annales* here quoted, the engraver has committed the error of designating a conventional representation as anamorphic, but as the coordinates are only employed with equal graduations, no anamorphosis could take place.

glance shows, not only the height of the tide at a given day and hour, but the intervals of time during which a vessel may find with certainty the depth of anchorage necessary, and the relative proportion of these intervals per month, etc. may also be deduced from this figure.

Examples of anamorphosis resulting from the use of graduated coordinates. — The second volume of the *Recueil de Tables à l'usage des ingénieurs*, published at the close of 1845 by M. Cousinery, engineer in chief, as a continuation of the *Recueil de Genieys*, contains (page 262) a graphic table which is the synoptic expression of all the combinations arising from the formula given by Prony for the movement of water in a conduit-pipe, by means of the principle of graduation of coordinates. This table was composed of three courses of straight lines and a fourth course of lines nearly straight. In the same volume will be found another anamorphic table, which shows the products of two factors, one of which is to be raised to the square.

This work proceded by some months the publication of our *Mémoire sur les tables graphiques et sur la géométrie anamorphique* (Ann. des Ponts et Chaussées, 1st half-year, 1846), and in it the author distinctly acknowledges that he borrowed from us the idea of the logarithmic transformation that permitted the rectilinear anamorphosis of the curves, which the graphical representation with ordinary coordinates would have allowed.

In addition to this, the report made to the Academy of Sciences by M. Cauchy, 11th September 1843, had imparted

a publicity to the principle of graduation of coordinates that permitted its application by any one.

At a later date, M. Collignon, in his fine work COURS DE MÉCANIQUE APPLIQUÉE AUX CONSTRUCTIONS, gave expression to the laws regulating the flowing of liquids in smooth new pipes, by means of anamorphic tables, according to the formulas derived from experiments by M. Darcy, and the laws of the uniform movement of water in open pipes, according to M. Bazin (*Hydraulique*, 1870, p. 190 and 253).

Other applications of the anamorphosis have also been made as follows: To the calculation of compound interest at different rates, in the *Tableaux sur les questions d'intérêts et d'assurances* of M. Eugène Pereire; to the expression of the resistance to rupture by the flexure of special double T iron, of various dimensions, by M. Louvel, in the *Portefeuille du conducteur des Ponts et Chaussées* (4th series, nos 6 and 7); to the correction of errors arising from the use of instruments for the approximative measure of distances, in the *Mémorial de l'officier du génie* (n° 18, 1868), by commandant Goulier; to the establishment of an *abacus of ranges* of lights intended for the lighting of the coasts, by M. E. Allard, now Inspector general « des Ponts et Chaussées » (*Mémoire sur l'intensité et la portée des phares*, 1876, p. 77); to the graphic expression of the formula of lenses, by M. Gariel, engineer, who, by means of an ingenious use of perspective, succeeded in improving an anamorphic Abacus obtained in the first place from graduated coordinates. (*Congrès de Clermont-Ferrand*, 1876).

N° 21 of the *Mémorial de l'officier du génie* (Paris, 1873) contains no fewer than nine plates devoted to the Abacus,

which give the results of calculations relative to the effects of the furnaces of mines. Among these Abaci, there are some constructed with Cartesian coordinates, but graduated coordinates are used for others, and circumferences are substituted for ellipses. These articles were written by Major Guillemot, who prepared his work in 1853, when he was only a lieutenant; Captain Ricourt, who died a commandant of Engineers at Gorée, January 1868, and whose graphic work was much more complete; Captain Delambre, who also completed the solution of Commandant Guillemot.

Graphic solution of numerical equations of any degree. — The solution of numerical equations has, it is well known, been the object of numerous and erudite researches. At the present time, so far as concerns methods of accuracy for the separation of roots and the numerical calculation of each, the efforts of mathematicians have been crowned with success. But as soon as the degree of the equation is superior to the third or especially to the fourth, there is the possibility of encountering operations complicated and laborious to such an extent, that tentative methods are preferred, empirical means, variables with each of the particular cases in question. Nevertheless a multitude of questions relating to engineering, require the solution of equations beyond the second degree. It was therefore desirable, at least from a technical point of view, that a method at once comprehensive and easy of application, should be devised in order to aid teachings which propound theories of extreme elegance, but do not sufficiently meet the requi—

rements of ordinary practice. This is the object proposed to be attained by means of the graphic method now about to be described. Given an algebraic equation of degree n with a single unknown quantity.

$$z^n + az^{n-1} + bz^{n-2} + \ldots + rz^2 + sz + t = 0.$$

Suppose that two of the numerical coefficients are variable, the two last for example, and we substitute x for s and y for t, the equation may be written in the form.

$$y = -zx - (rz^2 + \ldots + bz^{n-2} + az^{n-1} + z^n).$$

Now this equation of the first degree in x and in y represents a straight line for a determinate value of z. Give to z successive numerical values positive as well as negative

$$\pm(0{,}1,\ 0{,}2,\ 0{,}3,\ 0{,}4\ \ldots\ldots);$$

or trace on a plan the corresponding right lines, numbering them according to the values of z, and we shall have a graphic table showing approximatively the values of z corresponding to the point, the coordinates of which are $x = s$ and $y = t$, and consequently the values of the roots of the equation proposed, whatever may be its degree.

For example, given an equation of the third degree; eliminate the second term, viz : $z^3 + pz + q = 0$; describe successively all the right lines of which the equations are:

$$\begin{array}{ll} y = -0{,}1x - 0{,}001 & y = 0{,}1x + 0{,}001 \\ y = -0{,}2x - 0{,}008 \text{ et} & y = 0{,}2x + 0{,}008 \\ y = -0{,}3x - 0{,}027 & y = 0{,}3x + 0{,}027 \\ \ldots\ldots\ldots\ldots & \ldots\ldots\ldots\ldots \end{array}$$

unto $z = \pm 1,3$, and we shall have the Abacus represented in figure 9, by the aid of which any equation of the third degree may be approximatively solved, for the second term can always be eliminated in an equation arranged according to the decreasing powers of the unknown quantity.

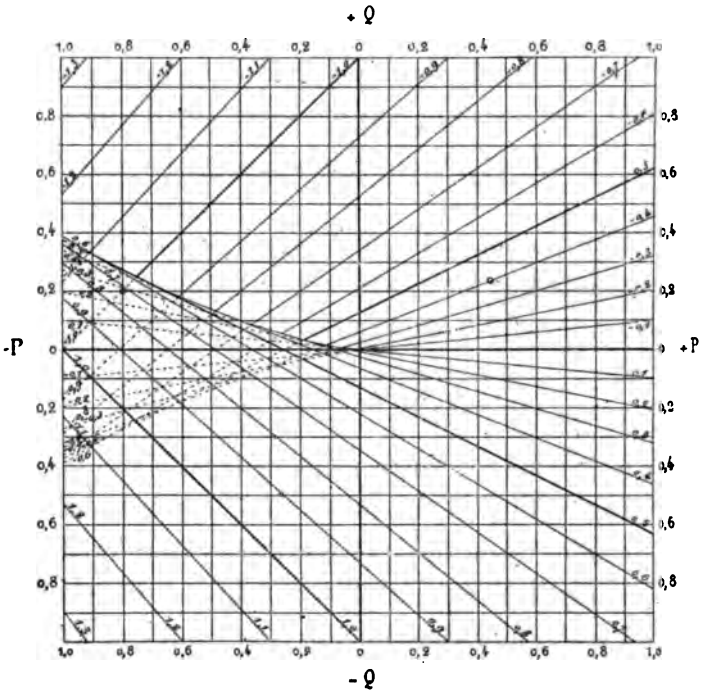


Fig. 9. — Abacus for the solution of equations of the third degree.

In this figure, if we commence with the abscissa $p = 0,8$ and the ordinate $q = 0,9$, we arrive at the point traversed by the oblique $z = 0,7$ in the square of $+p$ and $-q$. From which it may be deduced that the equation $z^3 + 0,8z - 0,9 - 0$ has only one real root, which is 0,7 nearly. In fact, the substitution of 0,7 in the first member gives a remainder

which is only 0,003, corresponding to an approximation of $\frac{1}{283}$.

In the same manner, given the equation $z^3 - 0{,}4z + 0{,}6 = 0$, if we enter the square of $-p$ and $+q$ by the abscissa $p = -0{,}4$, and by the ordinate $q = +0{,}6$, we arrive at the oblique $z = -1{,}0$, which is the exact value of the unique root of the equation.

In short, for the equation $z^3 - 0{,}845\,z + 0{,}165 = 0$, it will be found that, at the lower part and to the left of the square $-p$ and $+q$, three obliques pass through the point corresponding to $p = -0{,}845$ and to $q = +0{,}165$, and that these obliques are numbered $+0{,}8$, $-1{,}0$ and $+0{,}2$. In effect, these three values of z, substituted in the first member of the proposed equation, reduce it respectively to $+0{,}001$, $+0{,}01$ and $+0{,}004$, with an approximation which is $\frac{1}{800}$ for the first, $\frac{1}{100}$ for the second, and $\frac{1}{90}$ for the third.

In figure 9, the region that corresponds to the examples in which the three roots are real, is easily distinguished from that which corresponds to those in which there is only one. While, in this latter region, there is only a single system of obliques, in the first there are three which cross each other, and are separated by a funnel-shaped curve, to which all the obliques are tangent and which is, consequently, the *enveloppe* of all the right lines corresponding to the different values of z[1].

[1] In figure 1 of plate XCIX of the first half-year of the *Mémoires et documents des Annales des Ponts et Chaussées*, of 1846, and of which our figure 9 is a reduction, there is an error which consists in making the six obliques numbered ± 1, 1, ± 1, 2, ± 1, 3, terminate at the left side of the frame

The regions corresponding to the various numbers of real roots, may always be separated in this manner on the

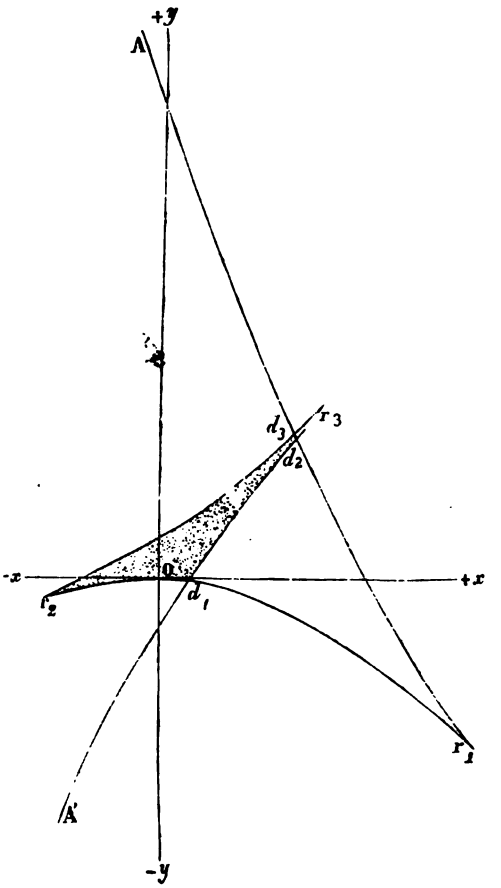


Fig. 10. — Outline of the *solutive* for an example of the fifth degree.

draught, by a curve similar in form, but of which the

much too near the axis of the p. The draughtsman had given the values ten times too small for the distances at which the obliques meet this edge, above the axis of p. The true values are respectively equal to $\mp$ 0,231, $\mp$ 0,528, $\mp$ 0,897. The error does not exist in figure 9 above.

ure becomes less simple, in proportion as the degree of e equation increases. In this way, the whole of the right ies represented by the equation

$$y = zx + 0,152^2 - 0,95z^3 + z^5,$$

hen z is made to vary from the tenth to the tenth of the nit from zero to $\pm 1,0$, will form a polygonal contour tan- ential to a curve, of which figure 10 denotes the principal haracteristics.

The central part tinted $d_1 r_2 d_3 d_2$ contains not less than ve courses of right lines crossing each other; there are ree in the region to the left of the contour $Ar_1 d_1 A'$, as so in the curvilinear triangle $r_3 d_2 d_3$, which proceeds from e right of the arc Ar_1, while there is only one in the part to e right of this contour. By making $x = 0,234$ and $y = 067$, a point is obtained which will fall in the tinted part the interior of the angle $+y\ ox$; the equation

$$z^5 - 0,95z^3 + 0,152^2 + 0,234z - 0,067 = 0$$

as therefore five real roots. By properly enlarging the cen- al part of the figure, three positive roots, 0,4, 0,5, 0,6, nd two negatives, $-0,7, -0,8$ will be found.

In the graphic constructions relative to equations of ven degree, there are spaces absolutely destitute of right ines, and of which each point is determined by a system of alues of x and y, to which the imaginary roots in the pro- osed equation in z correspond.

This elementary exposition is sufficient to show that the ew method may be practised by any one who knows how

to construct a right line determined by its equation[1]. Although the operator may neither have an idea of the general properties of equations, nor of the value, nor even of the reality of roots, nevertheless, by means of the construction of these successive right lines, the pencils which answer to the different roots, separate spontaneously, automatically so to say, and are distinguished from each other by means of the numbers which mark the corresponding values of z, and lead to the approximate values of the roots by simple readings.

Origin of this new method and the principles of geometry and analysis in relation with it. — No difficulty arises in connecting this new application of the graphic methods with the order of ideas, the origin and succession of which have been previously shown.

In the number of laws with three variables, with which it was natural to be engrossed at the moment of endeavouring to give a graphic expression to all laws of this description, was found the equation of the third degree, with the second term eliminated $z^3 + pz + q = 0$, in which the coefficients p and q are considered as independent variables. This application was also comprised in the dissertation of 1843, and specially mentioned in the report of Cauchy, who extended the solution to a numerous class of trinomial equations with three variables. The general extension of a mode of construction, so easily applicable to the third, to

[1] It is doubtless owing to its simplicity and practical character that this method now appears in an educational work, the *Leçons d'algèbre*, by Lefébure de Fourcy (Gauthier-Villars, 1880).

ations of a higher degree, naturally presented itself to mind, and figures were long ago established for an nple of the fifth degree, when the encouragement of evolent judges, decided the author to present to the lemy of Sciences the papers in which this idea is deve- d (13th and 20th December 1875, and 26th June 1876). e method in itself presents, as has just been seen, no culties for persons but slightly versed in mathema- it is not the less associated with considerations of netry and analysis the more interesting, as it establishes veen them a connection till now unperceived.

Thus the equation proposed with three variables, and ar in x and y, represents in space, what M. de la Gour- e called a *general conoid*, that is to say a skew surface a directing plane, which is here the horizontal plane he xy. All the horizontal lines of level have for their jections, in length and direction on this plane, the t lines of which the equations are given by the suc- ive values of z. The values of z, which furnish the s of the proposed equation, are the lengths of the vertical esponding to the point (x, y), comprised between the e of the xy and the different superficial divisions of the oid that this vertical meets. There is however no need to struct this conoid in relief, since the lines of level traced the plane and numbered, always enable the altitudes, re this meeting takes place, to be estimated at sight. he case of figure 9, and the region in which there are ee solutions, the thick lines indicate the superficial ision which may be considered visible, inasmuch as it is perposed by no other portion; which is the case with

respect to the values of z comprised between o and + 1,3 above, between o and − 1,3 below the plane of the xy. But in the portion limited by the funnel-shaped curve, for all the negative and even for the positive values of z, starting from the point of tangency with the curve, the corresponding right lines belong to portions of surface concealed, and are indicated by stippled lines, according to a known system of notation.

This curve, to which all the lines of the figure are tangential, and of which figure 10 represents the aspect for a particular equation of the fifth degree, is the projection of all the tangential points of the horizontal rectilinear elements with the surface of the conoid. Now the succession of these tangential points is the locus of the extremities of the right lines which measure the shortest distance between two of these consecutive elements, a remarkable geometrical position pointed out by Monge, who entitled it the *line of striction*, and which was commented upon by M. Chasles (*Correspondance de Quetelet*, vol. XI). On account of the prominent part which this enveloppe curve performs in the automatic separation of roots in the draught, we have proposed for it the appellation of *solutive*. The solutive is the projection of the line of striction; it is the *apparent contour* of the conoid, viewed from a point situated in the infinite above the plane of the xy.

These general geometrical properties result from the construction itself; they are of a purely intuitive character, and analytical considerations of a very simple description have led to the discovery of new ones.

In the first place, it is known that the equation of an en-

velope curve is obtained by eliminating the variable parameter z from the equation $f(x, y, z) = 0$ which contains it and the derivative of this equation with reference to z. In this manner is also obtained the particular solution of which the general integral is $f(x, y, z)$. The solutive is therefore the graphic expression of this particular solution. Its equation is of the same degree as the proposed, and the curve is also of a class equal to this degree. For what is called the number of the class is equal to the maximum number of tangents that can be drawn to a curve from a point situated in its plane; and on the other hand, the numbers of the tangents to the solutive, starting from a point (z, y) of its plane, express the values of as many real roots of the proposed equation, the number of which roots is, at most, equal to its degree. This remarkable equality between the *degree* and the *class* of the solutive, according to Plucker's laws, causes the existence of a certain number of cuspidal and double points, (Salmon, *Higher Plane curves*, Dublin, 1873) of which figure 10 gives a specimen for the fifth degree.

According to the theory of envelope curves, it is known how to calculate *a priori* the coordinates of the points of contact of each of their tangents. Here, these coordinates are both of rational form, and according to a definition introduced by M. Chasles, and generally adopted, the solutive which is its geometrical position is a *unicursal curve*.

Since then, in each of the points of the solutive, two consecutive and infinitely proximate tangents blend together, the proposed equation in z will have at least two equal roots, for every system of values of x and y that corresponds to one of the points of the curve. And what is made apparent by

analysis, the graphic method shows conspicuously, viz. that in order to find the equal roots of an equation in z, it is necessary that the result of the elimination of z from the proposed equation and its derivative with respect to z, should be equal to 0. In the same manner it is evident that the analytical determination of triple roots that may exist in the proposed equation, corresponds to the finding of the points of the solutive, in which three tangents infinitely proximate join, that is to say, at the cusps.

The consideration of the equation which has for its roots the squares of the differences of the roots of a proposed equation in z leads to new comparisons. In fact, the known term in this equation, is precisely the result of the elimination of z from the proposed and its derivative. It is therefore clear that the proposed equation will only have multiple roots as long as this term is null; and the equation of the solutive is (as we have seen) the result of this elimination. On the other hand, into this known term, exclusively composed of partial, entire, and rational terms in relation to the coefficients of the proposed equation, the two latter of these coefficients, viz. x and y, only enter to the degree n for x, to the degree $n-1$ for y. The degree of the solutive never exceeds the degree of the proposed equation.

The known term of the equation for squares of the differences is what is called in modern algebra, the *discriminant* of the proposed. The discriminant is one of the functions comprised under the general denomination of *invariants*. There exists a general relation, which, in an equation of any degree, enables the expression of the discriminant to be de-

duced from the value of the discriminant of the equation of a degree immediately lower. The new method of solving numerical equations clearly demonstrates an analogous relation between the solutives of equations of successive degrees. Thus the solutive of the equation of the third degree $z^3+xz+y=0$, a curve formed by the right lines of figure 9, and which is a semi-cubical parabola represented by the equation $4x^3+27y^2=0$, is the evolute of an ordinary parabola which is also the solutive of the equation of the second degree $z^2+xz+y=0$; only the semi-cubical parabola described as an evolute of the ordinary parabola which has for equation $x^2-4y=0$, has made a fourth of a revolution round its summit, by turning from right to left; and it has receded from left to right as far as the origin of the coordinates, by a quantity equal to 2; and this property is general. Thus the evolute of the solutive of an equation of any degree, will be the solutive of an equation of a degree immediately higher, when it is made to glide along the length of the axis of the y as far as the axis of the x, and afterwards turned in a sinistrorsal direction from a right angle. The length of the gliding is equal to $2m$, m being the coefficient of the term in z^2 in the proposed equation.

The solutive therefore always passes through the origin of the coordinates, and is tangential in this point to the axis of the abscissas. This property results, *a priori*, from the construction of the right lines enveloping it; it proceeds, *a posteriori*, from the composition of the discriminant and its derivative, which both become null when $x=0$ is made simultaneously with $y=0$.

In addition to which, it is manifest that every equation,

even transcendant, provided it has at least two terms with numerical coefficients, may be approximatively solved by a similar method, with the assistance of an Abacus with rectilinear lines; and that, in certain cases, it will be found expedient to employ coordinates with unequal graduations, which are not necessary for the solution of equations purely algebraical. The important part performed by the discriminant in finding roots has long been recognized; as we have just shown, the properties of the solutive furnish a geometrical interpretation, which extends to the connection between the solutives as between the discriminants of equations of successive degrees.

Special publications on the topics constituting the subject of this notice. — In his TRAITÉ DE GÉOMÉTRIE DESCRIPTIVE, M. de la Gournerie has devoted an entire chapter to an exposition of the methods developed in the *Mémoire sur les tables graphiques* inserted in the ANNALES DES PONTS ET CHAUSSÉES of 1846. These methods, and notably the anamorphosis, are now taught at the École Polytechnique (Cours de géométrie descriptive). They have formed a subject of instruction for nearly twenty years at the École des Ponts et Chaussées (Cours de routes), with their application to the preparation of plans and specifications. Abroad, M. Antonio Favaro, a distinguished professor at the University of Padua, appears to have been the first to bring them into notice in his works on the *calcul graphique* and the *statique graphique*[1]. M. Culmann, the eminent professor at

[1] *Sulle prime operazioni del calcolo grafico*, Venezia, 1872; *La statica grafica*, Venezia, 1873.

the *Polytechnikum* at Zurich, has made them the subject of a special exposition, in the excellent work upon the principles and developments of a science that is indebted to him for much; and like M. Favaro, he has expressed himself in terms which have not failed to excite sentiments of gratitude in the mind of the author, whose work is the subject of this friendly examination[1]. The Abacus of figure 9, for the general solution of equations of the third degree, has particularly attracted his attention[2].

The publicity thus given to the new methods, leads us to anticipate that they will speedily become more widely diffused, and enter more extensively into practical use. M. Gustave Hermann, professor at the École Polytechnique at Aix-la-Chapelle, doubtless had this object in view, when he published in German, a pure and simple reproduction of the *Abaque* ou *Compteur universel*[3], under the title of *Table de multiplication graphique*. A notice, at the commencement of the work, claims the right of M. Hermann to authorize its translation into French, English, or any other modern language. Another notice at the bottom of the engraved plate threatens legal proceedings against the publishers of such translations[4].

[1] «Wir glauben bei der Ausarbeitung graphischer Methoden diesen bedeutenden Aufsatz nicht mit Stillschweigen übergehen zu dürfen» (*Die graphische Statik*, p. 77 and seq., Zurich, 1875).

[2] «.....sehr schönen Tafel» (*Ibid.*, p. 84).

[3] *Das graphische Einmaleins*, etc. Braunschweig, 1875.

[4] The first French edition of the *Abaque ou Compteur universel* appeared in 1845; it was translated literally, plates and text, and appeared simultaneously in Germany under the title: *Beschreibung und Gebrauchsanweisung des Abacus oder der allgemeinen Rechnungstafeln*, Leipzig, 1846, Verlag von

To all appearances, the same laudable intentions seem to have actuated Dr Ch.-Augustus Vogler, who has published at Berlin in 1877, under the title of *Six tables graphiques pour abréger les calculs*[1], a brochure accompanied by plates, of which the greater part represent anamorphoses, and the first is also the reproduction of the *Abacus*, to which M. Vogler gives the title of « Table à calcul logarithmique ».

In the didactic treatise from which the six graphic tables are drawn[2], M. Vogler declares that for a period of seven years, he had been in possession of methods, by means of which, graphic constructions were substituted for numerical tables with double entry, and even of the principle of geometrical anamorphosis. A conviction that he could not be the first in possession of the idea, induced him to search for applications in technical literature. This search was without result, till at the close of 1874, his attention was attracted by M. Hermann

E. F. Steinacker; in England, under the title: *Explanation and use of the Abacus or French Universal Reckoner,* London, 1846, Joseph Thomas, 1, Finch Lane, Cornhill. A prior claim was submitted to the Academy of Sciences (26th November 1877, *Reports*, vol. LXXXV, p. 1012) and elicited a letter (6th January 1878) from M. Hermann, in which he alleges that the notoriety obtained in Germany by the anamorphic method, and the name of its author constituted of themselves reasons for publishing the work, and while making an apology, he expressed his sincere regret that the name of the author should have been omitted.

[1] *Sechs graphische Tafeln zum Schnellrechnen und zum Schnellquotiren*, etc. Ernst und Korn, in-8°. M. Vogler replied to the claim of priority directed against this publication, by observing that it was extracted from a more voluminous work in which the name of the promoter of the anamorphic method was mentioned several times.

[2] *Anleitung zum Entwerfen graphischer Tafeln*, etc., or INSTRUCTION POUR LA CONSTRUCTION DES TABLES GRAPHIQUES, etc.

(the same just mentioned) « to the system of logarithmic coordinates by Lalanne ».

« But », added he, « what particularly interested me was the perusal of a note by M. Kapteyn [1], in which the author, equally unacquainted with previous methods, has succeeded, by the same method as I (*sic*), in replacing the curves of the tables by right lines. » This method consists in the employment of conveniently graduated coordinates.

It does not appear that any new principle has been enunciated in this book. The most important figures are the reproduction or imitation of those annexed to the dissertation inserted in the *Annales des Ponts et Chaussées* of 1846. After explaining the construction and uses of the logarithmic Abacus, described and figured in this paper, M. Vogler refers to the publication of M. Hermann for fuller details; now M. Hermann was the first « to draw his attention to the system of logarithmic coordinates by Lalanne » (Preface). It could only be an inadvertence of the same nature, that gave rise to the assertion which attributes to M. Helmert

[1] *Note sur une méthode de graduation* (representation of curves by *right lines*), by Alb. Kapteyn, engineer at Ede (Gueldre), in the REVUE UNIVERSELLE DES MINES, etc., July and August numbers 1876, page 136. This note is an explanation of the principle of the graduation of coordinates, with the application to the establishment of some graphic tables anamorphosed in right lines, for the solution of questions of mechanical industry. « Subsequent to this note, » says the author « I found in Armengaud some graphic tables which induce me to suppose that this method *is not entirely new (sic)*, as I had hitherto believed. But he does not say how these tables were obtained, and gives no indication of the principles of graduation, so that the development of my theory and its general application retain their value under any circumstances. »

[1] *Zeitschr. für Vermessungswesen, 1876, Heft* I. It was only at the very

the method of constructing logarithmic formulas by circles; while the dissertation of 1846, in nos 33 and 34, expressly indicates the «successive anamorphoses of hyperbolas in right lines, of right lines into circumferences . . .» (See page 396 of the present Notice.) Now M. Vogler was in all probability aware of the contents of this paper, since he noted it (page 45 of his *Anleitung*), and characterized it as «a paper of tolerable scope, in which several examples would be found, some, interesting from a theoretical point of view, and others from the possibility of their practical application.» The late Cousinery, whose name is so honourably associated in history with the methods employed in graphic statics, is to the present time, erroneously mentioned among the constructors of curves of equal elements. In page 131 of the Tables de Génieys, it will be seen that two numerical tables were calculated by «the method of graphic interpolation»; they showed in metrical measures the thickness at the key and abutments for arches of different spans and heights of piers; but this method by no means supposes the consideration of the topographic plane with curves of

time that our notice was in the press that we could procure this number of a periodical collection, the organ of the German Geometrical Society and published at Stuttgard by Dr W. Jordan, professor at Carlsruhe, assisted by Dr F. R. Helmert, professor at Aix-la-Chapelle, and Dr J. H. Franke, trigonometrician at Munich. M. Helmert's paper, entitled *De l'établissement des tables graphiques à double entrée*, occupies ten pages and contains a plate. It contains no result which will not be found at least indicated or even definitively enunciated in the Notice in the *Annales* of 1846.

In page 48 of the same number will be found an article by M. Ch. A. Vogler, on the Logarithmic Abacus published by M. Hermann, in which the question of purely and simply reproducing a publication issued thirty years before is not mooted at all.

level. Between the one and the other, there is the difference which exists between the isolated sinusoids that express the variation in the height of the tide for each lunar day, and the curves of the numbered plane in figure 8, representing synoptically the law of the tides during an entire lunation.

In short, M. Vogler has neither considered the advantage to be derived from graphic constructions for the solution of equations, nor the application of the anamorphosis to certain natural laws, of which we know not the formula and only possess the numerical terms.

Nothwithstanding these inaccuracies and hiatus, we shall borrow from M. Vogler's book. For the periphrase « lines of equal element », that we had hitherto employed, he finds an excellent substitute in the word *isoplethe*[1]. It is a word admirably composed, fitted to pass into ordinary language, and we shall not hesitate to make use of it.

Retrospective glance. — In the preceding explanation as well as in the dissertation of 1846, we had occasion to cite many more French than foreign names. In fact, after Descartes, with whose name the illustrious Cauchy, in his report of 1843, desired to associate the parent idea of our theory; after Descartes, it is to Philippe Buache (1737-1759) and to Ducarla (1802), that we owe the idea of curves of level, and the employment of these curves on a plane which reproduces them on the scale desired and without any deformation in their relative positions; it is to Pouchet that we are indebted for his *Arithmétique linéaire* (1795) with

[1] Ἴσος, equal; and πλῆθος, value, quantity.

hyperbolas of equal power; it is from Terquem [1] that we derive (1830), the connection which he positively established between the numerical tables with double entry, similar to that of Pouchet, and the representation of surfaces on a plane; it is to all these men, assuredly of unequal merit, but who have left an enduring track on this road, that we must attribute the successive progress of an idea which appears at the present time to have completely entered into the domain of the practical.

A point not less worthy of remark is the influence exercised by a legislative measure on one of the most important particulars of this progress.

The following clause occurs in article 19 of the law of the 18th Germinal: « In place of the tables of comparison between the old and new measures, that had been commanded by the decree of the 8th May 1790, graphic scales shall be made for estimating these relations without the necessity of any calculation. »

It follows from this notice issued on the 22nd Frimaire in the year III by the *Temporary Commission of Weights and Measures* (signed: Lagrange and Haüy, secretary) and from the report made on the 9th Floreal of the same year, by Coulomb and Laplace, to the *Consulting Office of Arts and Trades*, that Pouchet's work had been considered very useful and adapted to the meaning and intention of the law. The

[1] « A geometrician whose admirable devotion to the propagation of science and whose ardour in encouraging the endeavours of others, sometimes caused his originality to be forgotten, Olry Terquem... » Such is the appreciative estimate formed by the eminent man who fills the position of perpetual secretary to the Academy of Sciences, M. J. Bertrand (eulogium on G. Lamé, 1878).

testimony of Pouchet himself is that, from these favourable opinions, and especially from that of the decree above-mentioned, he derived the strongest encouragement to continue his work and to augment it. « I have devoted myself, » said he, « to this third edition with the more confidence, since I have discovered the method of composing an universal table for all subjects. . . I have even found a means of dispensing with the compasses which served me to calculate, so that all possible combinations are furnished on my table by simple reading, as in a book. » (*Métrologie terrestre*, Rouen, 1797, Disc. prelim.)

To justify the title of *Arithmétique linéaire*, Pouchet considered himself under an obligation to supply a method for the addition and substraction of decimals, by utilizing the rectilinear assemblage of squares of the figure that represents the succession of equilateral hyperbolas. This manner of proceeding is as inconvenient as it is peculiar; and the idea of employing an arithmetical Abacus in which parallel obliques comprised in the formula $x+y=z$ should perform the same duty for addition that his hyperbolas $xy-z$ do for multiplication, appears to have completely escaped his notice. (*Ibid.*, page 147 et seq.) It is therefore a system widely removed from the purely empirical method, which replaces by numbered hyperbolas, the figures of a multiplication table after Terquem's synthesis.

In this description of history which relates to an idea, it is proper to mention, notwithstanding their slight importance in the kind of application we have in view, the isoplethes of an entirely different character, that Halley in the first place, and after him Euler, imagined on the sur-

face of the globe, lines of equal declination and equal magnetic inclination; the *isotherms*, *isocheims* and *isotheres* of Alexander von Humboldt; and going back to remote antiquity, even the meridians and parallels, terrestrial or celestial, which constitute the loci of the points of equal longitude and latitude, and are probably the most ancient isoplethes that have been considered. All these lines of equal element have doubtless a certain analogy to the curves of level; but these, more strikingly than the others, correspond to a *tangible* fact, which the most elementary levelling shows conspicuously and of which the graphic expression is not purely conventional, since it suffices by the simple view of the numbered plane, to furnish a resemblance of the relief of the ground.

In a passage in the second volume of the Tables de Génieys (page 259), Cousinery remarked the analogy subsisting between the rectilinear anamorphosis of hyperbolas, and the problem that Mercator and Wright had proposed, by lengthening the degrees of latitude in such a manner as to make the loxodromic line rectilinear on plain charts, that line which is so well understood by navigators and which is described by a ship crossing consecutive meridians at the same angle. This analogy is incontestable; but has it always performed the same part in the invention of the anamorphosis? The opinions of the learned men[1], deputed to report to the Academy upon the subject, were opposed to this hypothesis. They were apparently acquainted with plain charts and loxodromy, but they have made no mention of them. They

[1] MM. Élie de Beaumont, Lamé, and Cauchy, secretary.

ave even gone farther; for in a letter dated the 15th August 843, Lamé summed up in these terms, a conversation iat had just taken place between Cauchy and himself; This, » said he, « is the opinion of the illustrious mathe- iatician : « They may dispute with M. Lalanne the prio- ity of invention, with reference to the employment of the raphic plan in general, but the idea of the linear sections s novel and ingenious, and belongs to him exclusively. » Be- ween the explanation given by Wright, in 1599, of the me- thod employed by Mercator for the construction of his great chart of the world (Duysbourg, 1599), and the publication of the principle of the graduation of coordinates as a base of the anamorphosis, in 1843, no example of the same kind has come to our knowledge.

EMPLOYMENT OF GRAPHIC METHODS

FOR CALCULATIONS RELATING TO THE DISPLACEMENT OF EARTH.

It is known that, in all new projects such as roads, rail- ways, canals, etc. which involve the removal or displace- ment of earth, it is not sufficient to calculate the mass of earth in the cutting or embankment to be made, in order to modify the relief of the soil conformably to the object proposed. An exact statement is required of the manner of distributing the soil of the cutting on the embankment; it is necessary to determine the different parts into which each mass of earth should be divided, in order to be removed to as short a distance as possible; then the sum of the products of these different masses must be made in relation to the res- pective distances of removal, and this sum must be divided

by the total volume of the earth taken from the cutting, and the quotient will give the average distance of transport of the earth from the cutting to the embankment. It is true that this succession of calculations only includes the four elementary operations of arithmetic; it is equally true that it requires much care, and is both long and wearisome.

Let us take for example a part of a road or railway in which 21 *cross profiles* have been taken, numbered from 0 to 20, and consequently 20 spaces, some of which are found in both cutting and embankment. It is agreed that the smaller of the two numbers, expressing the cutting and embankment, corresponds to the deposit or employment of the contents of the cutting in the profile space itself, which is done at shovelling distance, or what is at least reckoned as such. We have then only to do with the excess; if there is an excess of contents of cutting, it is carried to the embankment at the nearest distance possible; if there is an excess of embankment space, it must be supplied from the nearest point of the cutting.

To simplify the calculation, it may be assumed that the volume in excess is entirely concentrated in the middle of the profile space, though this middle may not coincide generally with the centre of gravity of the volume.

Without entering into the details of the operation, we shall confine ourselves to showing, in the annexed table, the excess of cutting and embankment existing in each of the profile spaces, and which, with the distances of the spaces, supply the elements necessary for this operation.

DATA OF THE QUESTION FOR CALCULATING THE REMOVAL OF EARTH AND ITS EMPLOYMENT IN CUTTING OR EMBANKMENT.

INDICATION of the spaces.	DISTANCES between the centres of the spaces.	EXCESS of cutting.	EXCESS of embankment.	INDICATION of the spaces.	DISTANCES between the centres of the spaces.	EXCESS of cutting.	EXCESS of embankment.
	metres.	c. m.	c. m.		metres.	c. m.	m. c.
0-1.....		560	//	Brought forward.	413	1 750	1 005
1-2.....	49	140	//	10-11.....	18	//	
2-3.....	28	//	90	11-12.....	23	//	110
3-4.....	37	//	310	12-13.....	72	//	85
4-5.....	63	//	540	13-14.....	24	//	140
5-6.....	19	450	//	14-15.....	47	//	360
6-7.....	51	375	//	15-16.....	11	//	125
7-8.....	11	105	//	16-17.....	13	//	105
8-9.....	77	75	//	17-18.....	15	300	85
9-10.....	46	45	//	18-19.....	64	//	//
10-11.....	32	//	65	19-20.....			35
Carry forward.	413	1 750	1 005	TOTALS.....	700	2 050	2 050

By employing the elements of this table in the ordinary way, it will be seen that there are 19 partial volumes of cutting to be carried to the embankment, and that by multiplying each of these volumes by the distance of transport, 19 *moments* are formed, the sum of which is 31364o.

Then, by dividing the sum of the moments by the total volume of cutting 2 05o, we obtain the average distance $152^{m},995$ for quotient.

The graphic method requires no previous research with respect to the distribution of the contents of the cutting on the embankment. It is only necessary to construct rectan-

gular areas in echelons, and to measure their superficies in order to obtain the sum of the moments which, divided by the sum of the contents of the cutting (equal to that of the embankment), will give the average distance of transport from cutting to embankment.

The figure in the annexed plate, should be constructed in the following manner : above the base XY, draw the ascending vertical steps D_1, D_2, respectively proportional to the disposable cuttings corresponding to the points 1, 2; then, the descending vertical steps R_1, R_2, R_3 which may pass the ground line, and are also respectively proportional to the excess of embankment in points 3, 4 and 5; take the new series of ascending steps D_3, D_4, D_5, D_6, D_7 and so forth, to the last embankment R_{12}, which falls naturally on the ground line and blends with R_{20}, since in the numerical data of the question, we have supposed the contents of cutting equal to those of embankment.

Above as well as below the line XY, the sum of the tinted superficies is proportional to the sum of the moments required, and is equal to it if measured with reference to the scales employed. By dividing the area by the sum total of the volumes removed, we obtain the average distance of removal from cutting to embankment, as in the final result of the preceding table.

This is the explanation of the very simple method that, in a slightly different form, the author of this notice propounded for the first time forty years ago, after many efforts to simplify calculations of a nature at once harassing and tedious for engineers requiring to execute projects involving earthwork. He even applied to it the planimeter of Oppikoffer

nd Ernst, after adapting that instrument to the object roposed by the addition of a rule with movable slides. *Annales des Ponts et Chaussées*, 2e sem. 1840.)

But objections were then urged against the use of the meth-d. « You set before us », said one, « a very simple method or obtaining the average distance of transport from cutting o embankment, but in practice, the question of a similar verage estimated in block does not arise, and you must reviously consider the transport of the parts of the earth-vork that are to be taken in barrows from cutting to em-ankment, then those that are to be carted, and lastly those hat it may be most profitable to execute by the trolly or truck, drawn by a locomotive on a temporary or permanent line ». This objection was well founded, for it is evidently more economical to use a barrow for short distances, and to employ more effective means of transport in proportion to the increase of distances. It is possible then that the incompleteness of the solution proposed, as also the high price of the instrument adapted to it, may have impeded the diffusion of the idea that we submitted to the notice of engineers in 1840. Nevertheless the figure of which we have just explained the construction, and which was to be found as N° 13 in plate CXCIII of the first series of the *Annales* (2nd half-year 1840), contained the principle of separation of volumes of earthwork according to the kind of transport suitable to each. In fact, if it be admitted for example, that a distance of 100 metres constitutes the line of demarcation between transport by barrow and by cart, and which corresponds on the figure to 4 centimetres, it will be at once evident that the partial surfaces placed above the hori-

zontals D_1 2 *bis*, D_5 9 *bis* (lengthened) and 19-20, then below the ground line XY, viz. (5) and (6), (17) and (18). do not involve transport from cutting to embankment to a distance beyond the admitted limit. Therefore, it is only necessary to measure separately the partial surfaces to which a deeper tint has been given, and their total will represent the moments of transport by barrow, while the sum of the remaining superficies which compose the greater part of the figure, will be equivalent to the sum of the moments of transport by cart. By dividing each of the two partial sums by the volume to which it applies, we obtain the average distance relative to each of the two kinds of transport. Now the volume of the contents of cutting will be, for the barrow, the sum:

$$2\ bis\ D_2 + 6\ bis\ 6 + 9\ bis\ D_6 + 10\ bis\ D_1 + 19\ D_8;$$

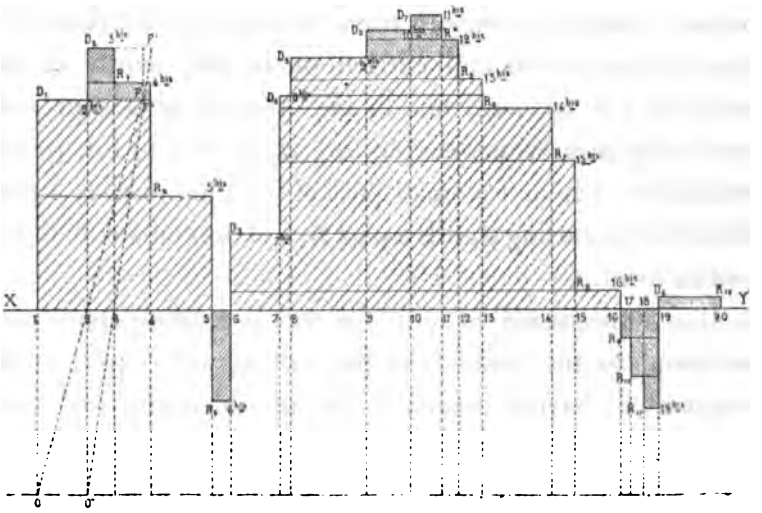
and for the cart, the difference between the total volume and the sum of the partial volumes.

The solution of the question is therefore effected in a manner absolutely intuitive, and appertaining to the essence of the problem, while the numerical results are obtained by simple operations resulting not from tentative but from direct methods, which do not involve the chances of error existing in the compilation of a table for calculating earthwork.

The practical rule to be substituted for this wearisome compilation, may be stated as follows :

Let XY *be a line containing the points of division corresponding to the centres of the profile spaces; establish in coincidence with these points, ascending orthogonal echelons, for the cutting* 1 D_1. 2 *bis* D_2, *etc., and descending ones for the embankment* 3 *bis* R_1.

4 bis R_2, *etc., proportional to these cuttings or embankments, and succeeding each other without interruption till the last, which should terminate at point* 20 *on the line* XY; *cut off either above or below* XY, *and parallel to this line, the projecting parts of which the length is less than that which corresponds to the transport by barrow; the figure will then be separated into two divisions, the*



superficies of which will represent respectively the sums of the moments, relative in the one case, to the transport by barrow, in the other, to the transport by cart, and if each of these superficies be divided by the sum of the ascending echelons which correspond to it, we shall obtain the average distance relative to each of the two modes of transport.

It is evident, that if there are three or four different methods of transport, according to the distances, a second and third deduction from the divisions parallel to XY may be effected with the same facility.

In addition to which, it will be perceived that the division of the figure by trenches with horizontal bases, must yield a total sum of moments equal to that resulting from the ordinary process, the table of which is the numerical expression, and the figure the graphic representation. Nevertheless, the method of proceding indicated by this figure is perfectly in accordance with the reality of things. We know, in fact, that the transport from cutting to embankment is always commenced and carried on in the vicinity of the points of passage from one to the other. This is expressed by the figure in which the cutting D_2 is seen to fill up the embankment R_1 and a small part of R_2; then in (5), a part 6 *bis* 6 of the cutting D_3 fills a part R_3 5 of the embankment R_3, and so forth.

It is unnecessary to add that the ascending steps proportional to the contents of the cutting will require to be augmented, having regard to the variable nature of their increase, and that in certain cases, much more unusual, the descending steps proportional to the embankment, will be diminished according to the assumed importance of the settlement of the contents of the cutting which are to fill it.

In the use of the figure an absolute equality is supposed between the sum of the cutting and the sum of the embankment. And in the end, this must really be the case, either by *raising* the excess of the volume of cutting, or by borrowing what is necessary to complete the embankment, for which the excavation from the main body of the line to be opened would not be sufficient. The construction of the figure will show, at the outset, the excess of cutting or embankment, by the position of the last point above or below

the ground line XY. The division by rectangular bands will afterwards enable the parts to be recognized, in which the transports are made to the greatest distance, and where it may consequently be expedient to borrow earth or to raise it higher. The measure of the greatest distances and the application of the corresponding cost of transport will also show, by comparison with the cost of accumulations and subtractions, the cases where it may be expedient to make them simultaneously, and the points where they will be most suitably placed. In a word, the method introduced forty years ago, by perfecting the planimeter of Oppikofer and Ernst, adapts itself to all the exigences of the problem, which consists in determining the best possible employment of the contents of a cutting in the formation of an embankment, and the most economical distribution amongst the various modes of transport and the distance appertaining to each. (See *Annales des Ponts et Chaussées*, 2nd half year, p. 27 et seq.)

A certain number of constructions exist, by the aid of which it is possible to obtain, without calculation, the sums of moments represented by the areas of the figure. The following method is one that we have proposed :

Let $1D_1\ 2$ *bis* 2 be any rectangle, of which it is required to find the area $= 1D_1 \times D_1\ 2$ *bis*. Let us take a point O in the extension of D_1, and draw O_2 that we produce to F, the point of meeting with $D_1\ 2$ *bis* also produced; if we take O_1=constant, and that 2 *bis* be measured on a properly graduated scale, a simple reading on this scale will give the area of the rectangle expressed in units of superficies or the moment expressed by the product of the base by the height.

Suppose that, in this figure, the distances of the profile spaces (bases *b* of the rectangles) be brought to the scale of $\frac{1}{2500}$, the volumes of cutting or embankment (height *h* of the rectangles) to the scale of $\frac{1}{20000}$; then, to obtain the true superficies *b h* of a rectangle expressed in units of superficies, it will be necessary to multiply by $2\,5000 \times 20\,000$, or $50\,000\,000$, the product obtained, when *b* and *h* are brought to the linear unit. Let us take the constant length from O to XY equal to $0^m,250 = \frac{1}{40}$ of the linear unit. It will be sufficient to multiply the length 2 *bis* F brought to metres, by $1\,250\,000$, to obtain the moment required. In the first rectangle on the left, the measure gives $0^m,022$: the superficies will then be $27\,500$. The exact calculation, with the data of the question, gives $560 \times 49 = 27\,440$; the error is about $\frac{1}{657}$.

Commencing from the points O, O′, etc., the succession of lines O 2 F, O′ 3 F, etc., has been traced, determining, on the upper bases of the rectangles, the segments 2 *bis* F, 3 *bis* F′, etc., proportional to the areas of these rectangles, and consequently, by bringing them to a convenient scale, giving the numerical values of the partial moments, the sum of which is required in order to deduce from it the average distance of transport.

It will also be seen how we may obtain, by a simple difference of lengths, the moment relative to one of the deeply tinted rectangles in the upper part of the figure. In fact, the difference between D_2F' and 2 *bis* F″, is the measure of the deeply tinted part of the top of this rectangle. This difference is the interval between F″ and the foot of the perpendicular F″ on D_2F'. With reference to the areas below the

ground line XY, analogous constructions are applied, after previously lowering them symmetrically above this line.

To generalize the conditions which have served for the preceding calculations, when the bases b of the rectangles are constructed to the scale $\frac{1}{m}$ and their heights h to the scale $\frac{1}{n}$, then, designating by C the constant distance separating the ground line XY from its parallel OO′ and by l the length proportional to the area of the rectangle bh, as we have $bh = Cl$, or $bh = l$, if we take C equal to the unit, we shall have $mnbh = Cmnl$; that is to say in the same manner, the value of the superficies of the rectangle or of the moment equivalent is equal to the number expressed by l measured by the scale $\frac{1}{mn}$; and if C becomes the half, third, or quarter of the unit, the length l becomes double, triple, or quadruple, which necessitates the reduction of the multiplier mn in the same proportion. The graduation of a movable scale, on which the moment or true area of the rectangle can be immediately read, must therefore be effected on the scale of $\frac{1}{mnC}$; and even without constructing this scale, we shall have the value of the moment required, by measuring l in relation to the unit, and multiplying by mnC.

So in the figure, the bases being constructed on the scale of $\frac{1}{7\,500}$, and the heights on that of $\frac{1}{20\,000}$, the distance O1 being equal to $0^m,025$, we have $m = 7\,500$, $n = 20\,000$ and $C = 0^m,025$; the scale will have to be constructed in the proportion of

$$\frac{1}{0^m,025 \times 7\,500 \times 20\,000} = \frac{1}{3\,750\,000},$$

or on a scale of 8 millimetres for a product equal to 10 000 000.

Similarly, after measuring the sum of the differences such as 2 *bis* F, D_2F' (we have only marked the constructions on the figure for the two first points O, O'), we find that the length of this sum is 84 millimetres, and we conclude that the sum of the moments is expressed by

$$0{,}084 \times 3\,750\,000 = 315\,000.$$

Now we have said that this sum, calculated with accuracy, is 313 640. The error is therefore 1 360 in 313 640 or about $\frac{1}{232}$.

The draughts made in the Office of the Direction of Railways are on the scale of $\frac{1}{5\,000}$, or $0^m,02$ per 100 metres, for the distances of the profiles (bases of rectangles), and $\frac{1}{10\,000}$ or $0^m,005$ per 1 000 cubic metres for the volumes of cutting or embankment (height of these rectangles). By taking $O1 = C = 0^m,05$, the lengths 2 *bis* F brought to metres, will have to be multiplied by $5\,000 \times 200\,000 \times 0{,}05$, or by 50 000 000, to express the corresponding moments in units.

In this notice we have confined ourselves to giving the practical rules of the graphic method, but the geometrical considerations upon which it is founded, are developed in an article of the Annales des Ponts et Chaussées (*Mémoires et documents*, cahier of August 1879) which appeared separately under the title of, *Exposé de deux méthodes pour abréger les calculs des terrassements et des mouvements de terre*, etc. (Dunod, publisher). The original idea will be found in a paper entitled : *Sur l'arithmoplanimètre, machine arithmétique et géométrique*, etc., published in the Annales (2nd half year 1840), as before mentioned.

It was quite natural that the same requirements, existing simultaneously in different countries, should give rise to solutions of the same description, and this circumstance occurred in reference to the invention of the method we have just described. In fact we find in the excellent work by M. Culmann [1], entitled : *Die graphische Statik*, a method for which we are indebted to M. Bruckner, a Bavarian engineer, and which presents a striking analogy to our own. From a note that the eminent professor at Zurich has been kind enough to send us, we learn that the Bruckner method was employed for the first time in the construction of the inclined plane at Culmbach, in 1844, that is to say four years after the publication of ours; and the circumstance that the Swiss engineers have more recently (says M. Culmann) adapted the planimeter to the method of M. Brucker, renders the analogy still more striking, since it was in that manner that we commenced our researches.

[1] See, in the French translation published by Dunod, 1880, the chapter entitled : *Mouvement des terres* (p. 33). This translation of the second German edition published at Zurich, 1874, is the work of MM. G. Glasser and J. Jacquier, engineers des Ponts et Chaussées, and Valat civil ingineer.

XXXIX

GRAPHIC TABLE

OF THE TIMES OF THE RISING AND SETTING OF THE SUN

AT ANY POINT OF THE TERRESTRIAL GLOBE

AND AT ANY EPOCH OF THE YEAR.

By M. Édouard COLLIGNON,
Engineer in chief «des Ponts et Chaussées».

The times of the rising and setting of the sun, at an point of the globe and at an epoch determined, depend o the latitude of the place and the declination of the sun a the moment in question. Let λ be the latitude, D the de clination, and H the time of setting reduced to degrees, i the proportion of 15° to an hour, then we shall have be tween these three elements the relation.

$$\text{tang.}\,\lambda\,\text{tang.}\,D = -\cos.\,H.$$

The table exhibited and the adjoining figure are only th graphic rendering of this formula.

Horizontal lines, drawn to distances tang. L from a poin taken for origin, represent the latitudes; perpendicular line meeting at the same point, represent the declinations by th angle which they form with the mean line of the drawing on the right, they are positive or northern, on the left, nega tive or southern. At the bottom of the diagram they termi nate in a curve, which gives the equation of the time fo the various epochs of the year. Each point of the figur

be regarded as the intersection of a horizontal, which sponds to a certain latitude, and of an inclined line

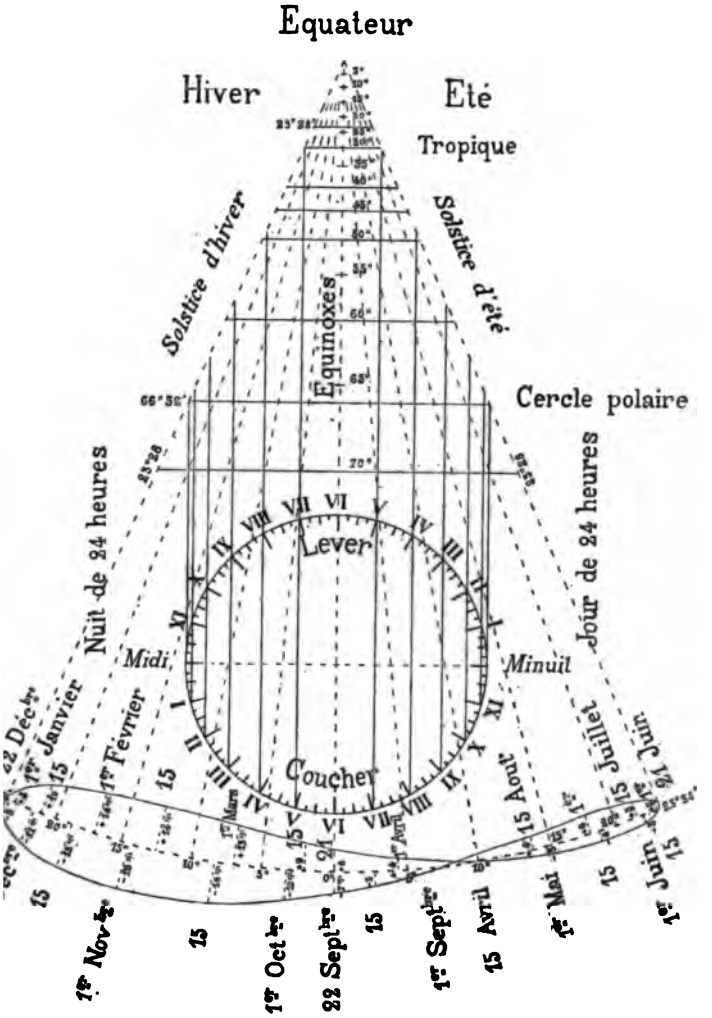


Diagram of the rising and setting of the sun. (True time.)

h defines a certain declination. The vertical carried igh this point, generally cuts the hour circle in two

points, one of which indicates the true time of sunrise, the other the true time of sunset. To find the correction for these times and to reduce them to mean time, it is only necessary to follow the line of declination to the point of meeting with the curve of epochs, and we shall find, according to the

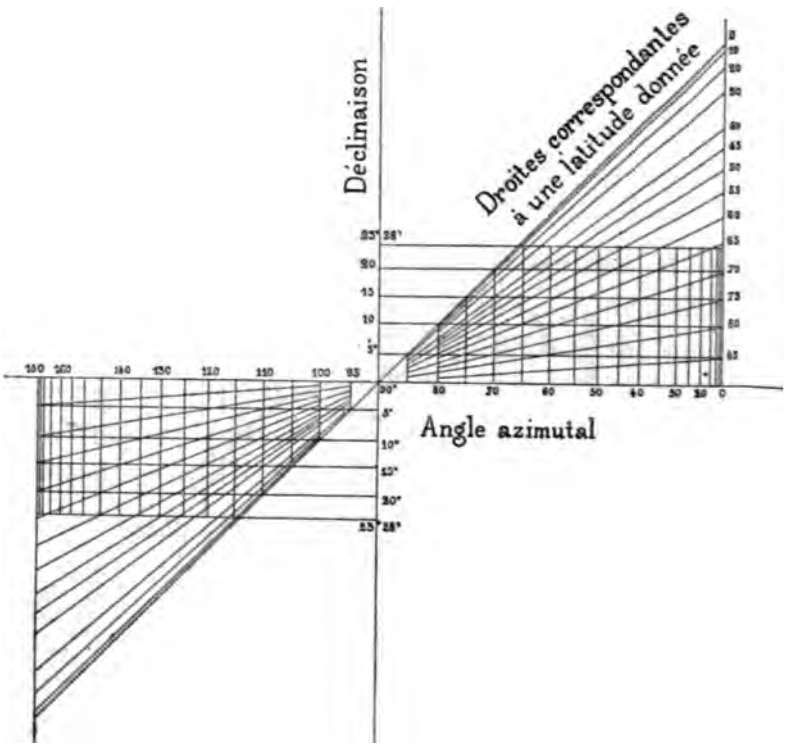


Diagram giving at sight the azimuthal angles of the rising and setting of the sun dependet on the declination and altitude.

epoch, and by interpolation if necessary, the additive *or* subtractive correction required to be made in the time indicated on the circle.

The table is arranged for northern latitudes, but it may

without difficulty, be adapted to the southern, by altering the sign of the declination, which is equivalent to changing the sign of the latitude. It will only be necessary to apply to the times read, the correction corresponding to the true epoch.

The second diagram in the plate is an analogous rendering of the formula

$$\sin. D = \cos. \lambda \cos. \omega,$$

which gives the ortive or occasive amplitude ω of the sun, i. e. the azimuthal angles comprised between the points of rising or setting and the direction of the North. The inclined lines, which meet in the centre of the plane, correspond to the latitudes, the horizontal to the declinations, and the vertical to the azimuths required; they are found near the vertical lines, and on the horizontal line which constitutes the base of the triangle formed by the figure. The same abacus, extended and completed, may serve to resolve at sight any rectangular spherical triangle.

For the theory and construction of these graphic tables, we refer our readers to an article in the *Nouvelles Annales de Mathématiques* (2nd series, vol. XVIII, 1879).

XL

ATLAS OF THE PORTS OF FRANCE.

Portfolio of charts and plans.
Four volumes of notices.
The charts are on a scale of $0^{m},0075$ ($\frac{1}{133\,333}$);
the plans on a scale of $0^{m},0002$ ($\frac{1}{5\,000}$).

A ministerial decision of the 24th October 1868, ordered the publication of an atlas of the maritime ports of France, and appointed a commission to arrange the basis of the work and to direct its execution.

In addition to plans of all the ports, the work contains charts simultaneously hydrographic and territorial, representing the landfalls of our principal harbours, also their means of communication with the interior, and notices furnishing the most important information respecting the approaches, the nautical conditions, the successive development, the present state and the statistics of each of the ports.

It will comprise eight volumes of text and one hundred and sixty-three plates.

The notices of the ports will be printed in a separate form, independently of their publication in the body of the work.

At the request of the engineers in chief of the maritime service, the plans of the atlas are transfered to stone, and

graphed for any number of copies, in order to be uti-
for the preparation of plans and for other require-
ts of the service.

he part published, consists of four volumes of text,
s of ports from Dunkirk to the embouchure of the
, and isolated notices of the ports of Boulogne, Dieppe,
e, Rouen, Honfleur, Cherbourg, Granville, Saint-
, Morlaix, Brest and Lorient; the operation of en-
ng plans of the other Ocean and Mediterranean ports
vancing towards completion.

he charts, plans, and notices of the atlas, may be pro-
l at the house of Challamel senior, nautical publisher,
has these documents for sale in Paris and the princi-
orts, at prices fixed by the administration.

nce the recent death of M. Léonce Reynaud, Inspector
ral, who had presided over the atlas Commission from
igin, the president has been M. Léon Lalanne, Inspec-
eneral, Director of the « École des Ponts et Chaussées ».
ie secretaries are M. de Dartein, engineer in chief,
is charged with the preparation of the engravings, and
hoisy, engineer in chief, with the impression of the
es.

ie other members of the Commission, are MM. Botton,
ctor general « des Ponts et Chaussées », Collignon, en-
r in chief, Inspector of the « École des Ponts et Chaus-
, and Caulet de Longchamp, chief of the Navigation
rtment at the Ministry of Public Works.

iief draughtsman : M. Huguenin, « conducteur ».

igravers of the plates, MM. Pérot and Hellé.

XLI

THE PUBLIC WORKS OF FRANCE.

Five volumes large folio with photographic plates.

In this work, the initial point was the fine collection of photographic views sent by the Ministry of Public Works to the Universal Exhibition at Vienna, and the most remarkable of those views are reproduced here.

Each of these five volumes is devoted to a special branch of the public works, and treats of its history, the conditions of establishment, statistics and principal edifices. The text is accompanied by maps, drawings in great number, and fifty plates by the new process of photo-typography.

The work is published under the auspices of the Ministry of Public Works and under the direction of M. Léonce Reynaud, Inspector general « des Ponts et Chaussées ». It was compiled by the engineers in chief, MM. Lucas and Fournié (1st volume: Roads and Bridges); E. Colligson (2nd volume: Railways); de Lagrené (3rd volume: Internal navigation); Voisin-Bey (4th volume: Sea-ports); E. Allard (5th volume: Lighthouses and Beacons).

Paris, Rothschild, publisher.

XLII

COLLECTION OF PHOTOGRAPHIC VIEWS.

Fourteen albums [1].

At the universal Exhibitions of Vienna and Paris, the inistry of Public Works exhibited a series of photographic bums, containing views of a considerable number of orks executed on the various ways of communication in rance.

The favourable reception accorded to this first collection, ıduced the Commission to renew, and at the same time to omplete it, and the work, as now exhibited, is enriched ŋ the addition of a great number of new photographs, hile of the former proofs, such as were considered imperect have been replaced by others, executed under more fa-ourable circumstances.

To facilitate inspection, the views have been arranged ıccording to the nature of the constructions.

The Ministry of Public Works is principally indebted for

[1] By permission of the Ministry, some of the negatives were borrowed by M. Rothschild, publisher, for the preparation of a work entitled: *The Public Works of France*, which appears under the auspices of the Ministry of Public Works. Under this title the work is included in the number of objects exhibited by the Ministry.

this collection to M. Magny, of Coutances (Manche), and M. Duclos, photographer, at Quimper (Finistère); the photographs of new works were executed under the direction of engineers of the different services.

SECOND PART.

MINES.

XLIII

DIRECTION OF MINES.

I

)GRAPHICAL AND STATISTICAL CHART OF THE MINERAL PRODUCTIONS OF FRANCE IN 1876.

This work is the reproduction, on a reduced scale, of the ıral chart which figured at the Paris Exhibition of 1878, the pavilion of the Ministry of Public Works. It was pre-ed by M. O. Keller, chief of the statistical service of mi-al industry.

It comprises the mines, lodes, peat-bogs and salt deposits ıt were worked in 1876; it shows the geographical po-ion of these various workings, and gives the weight of the ineral substances extracted from them during that year.

It is the first publication of a general chart of the mines France. Doubtless it might have been instructive to indi-e (by a distinctive sign) the numerous concessions of nes still unworked, by the side of those in full activity; t the smallness of the scale has caused this idea to be ındoned, in order to preserve the distinctness of the chart.

its present state, it already comprises 564 mines, viz. 9 of coal, 30 of asphalte and bitumen; 93 of iron, 8 of n pyrites or sulphur, 63 mines of lead, copper, zinc, etc., 1 21 of rock salt, including salt springs. It indicates be-es, the situation of the ores, peat-bogs and salt-marshes,

whether isolated or in groups. In this chart will be found the names of all these mines, lodes, or groups of lodes, and the names of the water-courses near which the peat or turf is principally taken.

Each of these workings is identified with the commune in which the chief operations are conducted.

Topographical signs of various kinds and different colours, enable the character and the object of the workings to be easily distinguished.

In this latter point of view, the mineral substances have been classified in nine categories viz.

	Production in 1876.
Coal and anthracite	16 635 853 tons.
Lignite	465 595
Peat	333 110
Asphalte and bitumen	176 070
Iron ore	2 393 340
Iron pyrites and native sulphur	144 549
Various ores (suitable for metallurgical treatment)	32 910
Rock salt	252 081
Sea salt	333 829

When the produce of a mine belongs to two categories — as in the case where coal-mines yield simultaneously coal, bituminous schists, and even iron ore — this peculiarity is specified by the union of two colours indicating these substances.

The names of the workings of the various ores are accompanied by letters showing the nature of the metals contained therein, viz. lead, silver, copper, zinc, manganese, tin, antimony, aluminium, etc. The same for the iron or copper

pyrites, and for sulphur. The mines that yielded, in 1876, more than 100 000 tons of coal, 50 000 tons of iron ore, 10 000 tons of salt are indicated by larger type.

The graphic representation of the weights of the different ores obtained during the year, consists in the employment of circles with graduated diameters, commencing with a diameter of 3 millimetres, to show a production of 10 000 tons; the surface of each circle is in proportion to the number of tons it is intended to denote.

For the iron and other metallic ores, the diagram indicates the production of the ore, raw or prepared, fit for metallurgical treament. A concentric circle, of a larger diameter and a lighter shade of colour, represents, where necessary, the tonnage of the ores in a raw state.

For peat and for sea salt, it has been judged preferable to employ squares equivalent in surface.

These figures are differently coloured, according to the nature of the ores to which they refer, and by their assistance, a brief survey of the chart will give a correct appreciation of the variety and importance of the mineral productions of any region in France. Each one represents the production of a group of workings fully determined and investigated.

It remains to show the method of proceeding adopted for forming and defining these groups.

No difficulty presented itself in respect of matters of a combustible nature, since the mines producing these substances are, generally speaking, grouped naturally in basins. Nevertheless, for the sake of perspicuity and precision, a few small centres of production, possessing no immediate

geological connection, have been united, either to each other, or to the great basin nearest to them. The mines of lignite, worked on a small scale, offer several examples of such groups. The distinct centres of production on the chart, have consequently been reduced to 32 for coal and anthracite, and to 14 for lignite, although the number of basins worked in 1876, variously designated, was 44 for the former and 23 for the latter.

The peat bogs have been divided into eight regions, according to their situations in the hydrographic basins of the Loire, the Garonne, the Rhone, the Seine, the Somme, the Escaut, the Meuse or the Moselle.

The mines of asphalte and bitumen have been distributed into four groups, corresponding to the basins of Autun, the Allier (including the Puy-de-Dôme), Seyssel (Ain et Haute-Savoie), and the Gard.

Iron mines and lodes, indiscriminately, have been united according to their geographical relations, and at the same time, in accordance with the geological conditions of their bearings and the mineralogical character of the ores; this has been done as far as was consistent with not making too many divisions. In order to effect these groupings in a graphic manner, it was found expedient to adopt the method employed in the cosmographic charts to denote the constellations, and by means of discontinuous lines, the workings intended to constitute the same group, and sometimes a long distance apart, have been connected with each other.

In this way, the chart represents 25 centres of production, and it seemed advisable to indicate them separately by a circle drawn inside the polygon, characteristic of each

group and agreeing approximatively with the centre of gravity of the figure. This has been done with the idea of applying to the various workings comprised in the figure, weights proportional to the tonnage of ores extracted during the year.

The twenty-five groups of mines and lodes of iron are by no means of equal importance. The number of centres of production furnishing more than 20 000 tons, is in fact reduced to twelve, which have yielded more than nine tenths of the total quantity; the principal are Nancy, Vassy, Privas, Autun and Bourges.

The mines of iron pyrites, sometimes slightly impregnated with copper, are worked for the manufacture of sulphuric acid, and form two distinct centres in the valley of the Rhône; one is situated in the department of the Rhône, the other in those of the Gard and the Ardèche. A small bed of marls impregnated with sulphur. which has been worked in Vaucluse, is indicated separately. The mines of lead, silver, copper, antimony, zinc, manganese, and tin, to which may be added a working of rock alum, and another of bauxite, have bee nunited, by the graphic method before mentioned, in six groups of great superficial extent, of which the two principal correspond to the central plateau of the Auvergne and the chain of the Cevennes.

The respective quantities of the various ores yielded by these mines, are mentioned and figured under the form of sectors in an angle of the chart.

Finally, the mines of rock salt constitute three natural groups; they are situated at the opposite extremities of France, in the Meurthe-et-Moselle, and in the Jura and Dax;

the latter include the salt springs of the Landes and the Basses-Pyrénées. The production of the salt marshes is, in addition, indicated by two squares of slightly different dimensions, referring, on the one hand to the salt of the Atlantic, and on the other to that of the Mediterranean.

To complete this « ensemble » of statistical information, a scale of proportions is placed at the side of the chart, and represents, by means of suitable colours, the importance of the production of coal, lignite, peat, asphalte and bitumen, iron ores, iron pyrites, other metalliferous ores, rock salt and sea salt.

Nothing appears so well calculated to convey a just idea of the natural wealth of France, as a chart of this description. By its aid, the distribution and relative yield of the mines and other mineral workings on the surface of the territory, may be comprehended with facility, as also the nature of the products pertaining to each region.

A collection of charts of an analogous character, prepared at certain intervals, of twenty years for instance, would afford a very interesting subject of study, since in such a work would be depicted the evolution of our mineral industry, and the recapitulation of the history of its development.

II

GRAPHIC REPRESENTATION,

1° OF THE DEVELOPMENT OF COAL-MINING IN FRANCE SINCE 1811.

2° OF THE PRODUCTION OF CAST AND WROUGHT IRON AND STEEL, IN FRANCE SINCE 1819.

(Two tables.)

The *summaries of the statistics of the administration of mines* contain much information of great interest respecting the

development of the coal and iron industries in France. Certain hiatus occur in these documents, from the date of 1787, but from 1811 they record without intermission, and year by year, the production, importation, exportation and consumption of mineral combustibles. From 1833, the year in which the Ministry of Public Works commenced the publication of these summaries, they contain amongst other facts, the average price of combustibles, the number of mines and of miners.

Information of an analogous character also appears with reference to the production of cast and wrought iron from 1819, and of steel from 1826; these statistics are completed by the average prices of sales from the year 1833.

The Director of Mines has appointed M. Keller to undertake the graphic representation of these valuable details, so that the general progress of these industries may be comprehended at a glance, and the annual fluctuations to which they are subjected, may be carefully considered.

The mode of representation adopted, takes for its base some orthogonal coordinates, the different years being graduated in echelons on the line of the abscissas.

The first table relates to the coal industry, and represents, from 1811 to 1877, the quantities of coal; 1. yielded by the French mines; 2. exported; 3. imported from foreign countries; 4. the consumption in France.

The importation is shown at the upper part, and in addition to the production; the exportation is given at the bottom of the table; so that the consumption is shown by the simple difference of the surfaces, represented in varied tints. That representing the importation is divided into three zones of

different colours, according to the place whence the coals came (Belgium, England, Germany).

In the same manner, the surface corresponding to the production of the mines of the country is divided into a series of superposed zones, which show the annual production of each of the principal basins. This method enables us to comprehend at a glance, the successive phases and relative importance of the working of mineral combustibles in the basins of Valenciennes, the Loire, Alais, Creusot and Blanzy, Commentry, Aubin and Aix; and it shows distinctly the quantity contributed by each basin to the total annual production since the year 1833.

The ordinates of two lines more or less broken, and of a red colour, show the average annual prices of the combustibles consumed in France at the mines themselves, and at the places of consumption. Two other lines denote the number of mines worked, and the number of miners.

The second table consists of three parts, and refers to; 1. cast-iron, 2. wrought-iron, 3. steel.

Surfaces variously tinted show;

The total production of cast-iron, divided into charcoal-iron, coke or mixed iron.

The total production of wrought iron, divided into charcoal or mixed iron, coke iron, for rails.

The production of steel, divided into puddled and forged steel, also steel made by the methods of Bessemer, Siemens and Martin, cast, cement or blister steel.

Red lines more or less broken, and traced in each of the three divisions of the table, indicate the average prices of the various products from year to year.

III

CHART OF THE PRODUCTION, CONSUMPTION, AND CIRCULATION OF MINERAL COMBUSTIBLES IN FRANCE DURING THE YEAR 1872.

This chart is on a scale of $\frac{1}{1\,000\,000}$th, and was prepared at the Ministry of Public Works in 1875, by M. le comte de Vassart d'Hozier, engineer in chief of Mines, according to documents arranged by the Statistical Service of mineral industry.

It was published in the Summary of the statistics of the Administration of Mines, in 1870, 1871 and 1872.

The production of mineral combustibles is shown for each basin by a square, the surface of which is regulated in proportion to the quantity extracted in 1872, the square of 1 millimetre of superficies representing a production of 10 000 metrical quintals or hundred-weights.

The quantity of coal consumed in each department is represented in a similar manner, by a circle having the chief town for its centre. The originality of this map consists principally in the plan of the lines of circulation, railways and navigable ways, followed on the one hand, by the combustibles of the country, and on the other, by the coals imported from Belgium, England, or Sarrebrück. A special colour is assigned to the combustibles proceeding from each of these four localities, to indicate the lines of circulation, as well as to show the quantities consumed in the departments. These quantities may be approximatively estimated at the first view, according to the surface of the differently tinted sectors which present circles traced round the chief towns.

For the lines of circulation in the interior of the country, the tints are alternated when combustibles of various origins are conveyed by the same way of communication. Lines of a very distinct character, drawn beyond the coasts, denote the courses of maritime circulation.

The names of all the producing basins are given on the chart, as well as the numbers of metrical quintals of combustibles, yielded by each basin or consumed in each department.

IV

STATISTICS OF MIMERAL INDUSTRY AND STEAM MACHINERY IN FRANCE AND ALGERIA (1876-1877-1878.)

This is the latest volume of the collection commenced by the Administration of Mines since 1833. It includes, under the form of tables, preceded by explanatory details, the information collected by the engineers of Mines in each department, and arranged by the Statistical Service of mineral industry at the Ministry of Public Works.

XLIV

NATIONAL SCHOOL OF MINES[1], PARIS.

INSTITUTION AND OBJECT OF THE SCHOOL.

This School was first instituted in 1778, and subsequently re-established in 1816. The control is vested in the Minister of Public Works, and the principal object of the School is to furnish the training and instruction necessary for the engineers required by the Government for the service of the Mines.

Independently of the *engineer* students, the School receives private students, foreign students, and free students.

The *engineer* students, who are taken exclusively from those leaving the Polytechnic School, are alone eligible for the Government service, and are nominated by decree.

The private students are prepared for the various positions offered by commerce and manufactures, and in particular to enable them to become engineers or directors of mines or mineral works.

They are admitted by competition, conformably to the annexed double programme.

The *foreign* students are admitted by a decision of the

[1] In this article the English word «School» is used on account of the special character and object of the studies pursued at the «École des Mines». It is not entirely satisfactory, but the translator does not feel at liberty to substitute «college» or «institution». (*Translator.*)

Minister, at the request of the ambassadors or chargés d'affaires of foreign powers, on the condition of successfully passing an examination with regard to competency, before the Commissioners for competitive admission, and this examination takes place at the School of Mines once a year, in the latter half of the month of October.

The free students are, at their own request, simply authorized by the Minister to follow the courses of lectures and practical studies of the Scool. The private, foreign, and free students are expected to pay to the Secretary of the School a sum of 35 francs for wear and damage of instruments etc

The course of study is identical for the various categories of students, but the foreign and free students can only participate in the practical studies, in proportion to the number of places at disposal in the laboratory and drawing school.

At the close of each scholastic year, the engineer and private students pass examinations in the courses followed. The foreign students have the option of presenting themselves, but the free students are not admitted to these examinations.

On leaving the School, the engineer students are appointed engineers of the 3rd class, and the private students, whose acquirements are satisfactory, receive a brevet of merit, and are authorized to bear the distinction of breveted students *of the Paris National School of Mines.*

The foreign students receive simply the brevet of merit.

PREPARATORY COURSE.

To facilitate admission to the place of private students,

preparatory courses were instituted at the School of Mines, by a ministerial decision of 26th December 1844. These courses are followed by two categories of students.

The *honorary students of the preparatory courses* are admitted by the Minister, after a competitive examination, and the free students, either French, or foreign, are simply authorized by the Minister, on making personal application.

The students of the first only of these divisions, are required to pass an examination at the close of the scholastic year.

Candidates for the position of honorary student in the preparatory course, must fulfil the conditions required in the annexed programme. (Preparatory courses.)

The preparatory studies consist of four oral courses of lectures and of practical exercises.

The courses comprise :

1° Ideas of infinitesimal analysis and mechanics;

2° Descriptive geometry, pure and applied;

3° Physical sciences, in relation to gas and vapours, heat and optical instruments;

4° Chemistry in general.

Two of these courses consist of 25 to 30 lectures, and the other two of 55 to 60 lectures, given from 7th November to the end of May.

The programme of the courses of lectures is the same as that of the studies required for admission to the places of private students, with the exception of geography and cosmography.

The practical exercises consist in geometrical drawing, tinting, and shading.

COURSE OF THE SCHOOL OF MINES.

The principal objects of the instruction given at the School, are the opening and working of mines, and the treatment of mineral substances.

It embraces three years of study, and comprises, in addition to the lectures, practical exercises and travelling studies.

The students of the *first year*, attend the seven courses of the working and machinery of mines, metallurgy, mineralogy, assaying, geology, paleontology, and surveying.

The students of the *second year*, attend the second part of the four courses of working of mines, machinery, metallurgy, assaying and geology.

The students of the *third year*, the five courses of railway construction, mining legislation, administrative law and industrial economy, agriculture, technical geology and military fortification.

The oral teaching comprises in addition, German and English, and the students are compelled to attend the course of one of these foreign languages.

The oral courses open each year, from the 7th to the 15th November, and close on the 15th April.

The practical exercises are thus divided :

During the term of study, the students of the first and second year work alternately in the laboratory and the drawing school; they also study the collections of the School of Mines and visit the manufactories and workshops in the neighbourhood of Paris.

After the May examinations, the students of the first year are exercised in chemical analysis till the 15th July, and in surveying till the 15th August. The vacation commences at that date, but they are expected to visit, for three weeks in September or October, one of the principal mining and smelting districts in France or Belgium.

During the first fortnight in June, the students of the second year attend a course of geology under the direction of their professors, and in the summer they visit various mining and manufacturing districts, in accordance with a programme approved by the Council of the School. On their return, they communicate the results of their observations in reports illustrated by drawings and sketches numbered.

Each student of the third year is expected to prepare a plan of working a mine, and a system of metallurgy according to bases fixed by the Council of the School, and the engineer students terminate the third scholastic year by a second journey for instruction, of about a hundred days. On their return they are obliged, as before, to prepare reports on the various establishments to which their attention has been drawn.

The second journey is optional for the private students.

INTERNAL REGULATIONS.

The students are expected to remain at the School every day during the hours allotted to the courses of study and practical exercises, neither can they leave the School before the appointed time, unless authorized to do so by the Inspector of studies or the Director.

A muster is made, in order to ascertain the presence of the students at the time appointed.

No student is allowed to be absent for one or more days, without the permission of the Director or Inspector of the School.

For constant attendance at the courses and practical exercises, marks are awarded to the students, which influence their definitive classification. Failure in attendance, or want of diligence, involves the loss of a certain number of these marks, and renders a student liable to expulsion from the School.

EXAMINATIONS.

Examinations take place at the close of the scholastic year upon all the subjects of study, including the foreign languages (German and English).

All include a written composition, in addition to the oral examination.

Rising from one division to another, and the definitive classification of the students at the period of leaving the School, depend upon the number of marks obtained in all these trials collectively, including constant attendance at lectures and practical exercises.

On leaving the School, the engineer students choose, in the order of classification, among the residences or positions vacant, and the students who have successfully passed the examinations required, receive the *brevet* mentioned at the commencement of this notice.

Prizes are awarded to the engineer and private students who have distinguished themselves by their work at the School, or by their travelling journals. These facts are mentioned in the brevets.

The authorities of the School cannot *guarantee* appoint-

ments for the private students, but generally speaking, the influence and connections of the School are sufficient to procure positions more or less lucrative, for the greater part of the good students.

ASSAY OFFICE FOR MINERAL SUBSTANCES.

This office has been established near the laboratory of the School of Mines since from the year 1845. Its special duty is to make analyses of mineral substances, which may be required by the various industrial interests, proprietors of iron-works, mines, etc. Any person wishing a substance to be assayed must leave the specimen at the School of Mines, accompanied by the necessary details of its locality and the geological conditions of deposit. No payment is received for assays made in the interest of mining. A report of the proceedings of the Assay Office is published every year in the *Journal Officiel.*

From the establishment of the Assay Office to the 1st January 1880, no fewer than 23 200 analyses have been made of mineral substances of the most varied descriptions. Amongst the most numerous may be noticed those which relate to the different clays and silicates; limes, cements, and mineral substances of a combustible nature; fresh and mineral waters; metals and alloys, castings and steel; ores of silver, cobalt, nickel, copper, tin, iron, manganese, mercury, gold, lead and zinc; phosphates of lime and mineral manures; iron pyrites and lastly vegetable soils.

An account of part of these operations has been published under the direction of M. A. Carnot, professor and director of the Laboratory of the School of Mines. The analyses of

French and Algerian iron ore; of the potable and mineral waters of France and of French phosphates of lime, form three small books which appeared in 1878. The assays of combustible minerals have been recently published in the « Annales des Mines ». These various publications are shown in the glass-case of the School of Mines at the Melbourne Universal Exhibition.

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XLV

GRAPHIC STATISTICS

OF THE PRINCIPAL IRON ORES AND DEPOSITS

OF PHOSPHATE OF LIME IN FRANCE.

In 1878, the Administration of the School of Mines exhibited in Paris two *mosaic charts* constituting a figurative representation of the principal types of iron ore and deposits of phosphate of lime in France.

With this view, a chart of France, on a scale of $\frac{1}{320,000}$ and divided into departments, was formed of a plastic material, and in this ground, specimens of iron appreciably cubic, 4 centimetres square, were set as in mosaic; the pulverulent or granulated ores were enclosed in glass boxes of the same cubic dimensions. The cubes were all set to a depth of 2 centimetres 1/2, in such a manner as to form a relief or projection of 1 centimetre 1/2, from the plaster ground.

A work of the same character, and executed under similar conditions, was formed to represent the principal deposits of phosphate of lime in France.

The two mosaic charts were returned to the School of Mines, but photographs of these charts have been taken, and two have been sent to the Melbourne Exhibition by the authorities of the School of Mines.

These photographs show, in some measure, the geographical and natural distribution of the principal deposits of

iron ore and phosphate of lime throughout the territory of France.

This method of rendering the statistical geography of the iron ore and phosphate of lime in France, visible at a glance, was planned, proposed, and executed by M. DUPONT, Inspector general of Mines, Inspector of the School of Mines, with the aid of M. GUYERDET, preparator of the Geological and departmental collection, under the direction of M. DAUBRÉE, Inspector general of Mines and Director of the School.

XLVI

EXPERIMENTAL GEOLOGY [1].

IMITATION OF THE FAULTS AND CONGENERIC JOINTS

IN THEIR FORM, PARALLELISM,

AND DISTRIBUTION IN ORTHOGONAL AND CONJUGATE SYSTEMS.

By M. DAUBRÉE,

Member of the Academy of Sciences, Director of the Paris National School of Mines.

Principal facts observed relative to faults and joints. — The subject of faults has naturally engrossed the attention of miners since the close of the last century, when the mineralogist Werner, demonstrated that metallic lodes originate in their filling up. In the numerous districts where lodes are found, the faults have been minutely studied, and instructively figured, in horizontal projections and vertical sections. In coal mines, the field of operations is constantly disturbed, by reason of the relative dislocation which occurs along the inner sides of the strata. The different types of faults have been studied with geometrical precision, and in this respect, there are few that have not furnished information of a characteristic nature. Here again, theory is indebted to practical observation for valuable data upon this subject.

Irrespective of the working of mines, faults have consti-

[1] In this, Notice, the geological terms employed, are, for the most part, taken from Sir Charles Lyell's «Principles of Geology». (*Translator.*)

uted the subject of much study, for their influence on the earth's crust is of paramount importance, since they divide it into innumerable compartments, ressembling voussoirs, and are as lineaments, to which the terrestrial features of relief coordinate.

The fissures designated by the appellation of joints, though of smaller dimensions than the faults, have also been remarked for a considerable period, either on account of their great number, or chiefly that in certain cases they intersect each other in parallel systems, and with sufficient regularity to resemble crystallization. These dispositions have been denominated pseudo-regular, by reason of this resemblance, and are found in rocks of various kinds, particularly quartzite, quartzose, sandstone phyllite, limestone, coal and granite, in which the parallelopipeds are often rectangular. It not unfrequently occurs that the joints permit the rock to be divided into very small polyhedrons, in a manner resembling the circumstances attending the cleavage of crystals properly so called.

Without presenting this disposition of parallelopipeds, the joints exhibit a remarkable symmetry, and this is seen in the granite polyhedrons that Ramond found on the summit of Mount Perdu, and the angles of which he measured carefully, and figured as being probably the results of crystallization.

Elsewhere, the joints intersect each other without apparent regularity, but they are so numerous that it is difficult to obtain new fractures in the rock, even when divided into small fragments, and of this character, the Cretaceous limestone, found in a part of the chain of the Corbières, is an

example. Notwithstanding the persistent and searching investigation to which the faults have everywhere been subjected, both in their forms and modes of grouping, the cause of these great fractures still remains unknown.

Vague suppositions have been hazarded respecting them; they have been attributed, for example, to the molecular action exercised on the external envelope of the globe by heated masses of a pasty consistence that support it. This obscurity was the principal cause that induced de Boucheporn to seek an explanation of their parallelism by means of a most daring hypothesis, in which he attributes them to ruptures operated parallel to the different equators that our planet must formerly have possessed, in the changes of axis and rotation. The same ignorance prevails respecting the origin of the joints. The explanations attempted to be given may be reduced to three : a kind of crystallization; contraction; mechanical action.

With better foundation, the theory of mechanical action may be adopted to explain the joints belonging to the category which now engages our attention.

1. The constancy, for great distances, of the orientation of certain systems of joints, has been already ascertained by Sedgwick, de la Bèche, Phillips and others. In Cornwall also, the fact that these joints preserve their direction in passing from the granite to the schists, has been distinctly recognized. After observing these two facts, de la Bèche, with characteristic perspicacity, concluded that the joints could not result from a process of contraction, and he ascribed them to polar action, a theory also employed, at that time, to explain the schistose character of certain rocks.

Taking into consideration the present state of geological knowledge, this permanent orientation in the joints, ought, on the contrary, to cause an approximation to the faults, the mechanical origin of which is no longer in doubt, and which are in the same manner independent.

In addition, it is known that in many districts, the joints are connected with the faults, properly so called, by various intermediaries.

2. The direction taken by the joints in Yorkshire has been the subject of a number of observations on the part of another eminent geologist, John Phillips, who collected them on a map of bearings, and the result is that two directions predominate largely in relation to the others, and that these two directions are perpendicular to each other.

3. Mr. Harkness, in an interesting dissertation on the joints in the vicinity of Cork (Ireland), records a characteristic fact, viz. that in the proximity of the joints, the fossils are deformed and distorted, and this singularity has been noticed in other localities, which suggests the idea of mechanical action.

An important result was obtained by considering the joints as the effects of rupture, in the same manner as the faults, which differ from them especially in dimensions. Albeit, only very indefinite conceptions had hitherto been formulated, respecting the cause of these ruptures; thus, Mr. Harkness, after asserting that the carboniferous limestone in the environs of Cork, has been acted upon by considerable forces which have bent and distorted the strata, considers that these forces have, at the same time, determined certain systems of joints and a cleavage; nevertheless, he adds that

simple pressures cannot account for the complex assemblage of joints so frequently observed in the limestones.

4. There is still a character which must not be lost sight of, and which gives additional weight to the preceding considerations in favour of the mechanical origin of the joints.

It is frequently remarked that, in the production of the joints in pudding or conglomerated stones, pebbles of quartz or porphyry are cut by them in the cleanest manner. I have often had the opportunity of observing this fact in the sandstones of the Vosges, for example, in the escarpments forming the summit of Schneeberg, and it is of frequent occurrence in the porphyritic conglomerates in the form of obelisks, which sustain the old castle of Baden-Baden. A layer of crystallized quartz is frequently seen on the faces of the pebbles divided in this manner, and the « Old Red Sandstone » of Waterford (Ireland) may be also cited as affording analogous condition. A powerful cutting or shearing action has therefore operated in the formation of the joints.

In brief, the characteristic feature manifesting itself in the innumerable fissures of the terrestrial crust is a parallelism which is reproduced in the great, equally with the small fractures, in the faults as in the joints. Past experience had not hitherto brought to light this fundamental fact.

The analogy which shows in the joints a smaller kind of fault gave rise to the expectation that the general problem might be approached experimentally, notwithstanding the fact that these latter surfaces of rupture often exceed tens of kilometres.

Fractures produced in a thin crust, by an un-

dulating movement. — The method that I have employed consists in causing an undulating movement, which breaks a very thin plate across which it is diffused. Thus, by the vibration of a rectangular vessel containing a solution of bicarbonate of lime, on the surface of which a pellicle of limestone is concreted by means of decomposition, we shall see this species of membrane rent in several places.

The undulations spreading to the small sides of the vessel, cracks are produced, the most prominent of which have a tendency to follow the direction of the rims of the vessel, and consequently to be perpendicular to each other. But this result, although worthy of attention, does not afford an explanation of the important geological facts just mentioned.

Three other processes have been adopted for the purpose of reproducing terrestrial fractures in their principal characters; two of these have succeeded in producing an imitation of the faults and their congeneric joints, forms, association, parallelism and distribution into orthogonal or conjugate systems. In these methods torsion and deformation are produced by pressure alone. In the third the fracture is produced by flexure.

Fractures obtained by torsion. — The idea by which I have been guided is that by inflecting a thin plate, originally plane, in such a manner as to give it the form of a ruled surface, it would be possible to break it in accordance with the straight lines, in relation with those generating this new surface.

A long rectangular plate or slice of the substance to be examined, is held by one of the small sides, between

two jaws of wood drawn together by screws, and forming a kind of vice (fig. 1); the other end is set in a wrench, and wedged up by means of cardboard. By turning the wrench round a horizontal axis, a torsion is caused which soon produces a rupture.

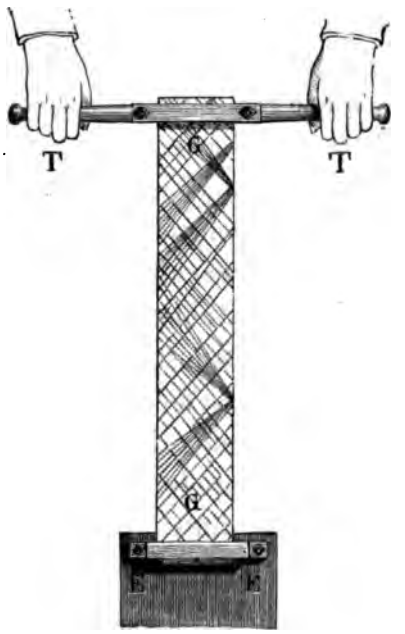


Fig. 1. — Apparatus for producing the rupture of a plate of glass by torsion.

The first series of experiments, on plates of gypsum 12 millimetres thick, gave a small number of fractures. In certain cases, fractures were obtained having a marked tendency to be parallel to each other, while others were nearly perpendicular.

The experiments were more successful with plates of glass. These are from 80 to 90 centimetres in length by 35 to 420 millimetres in breadth and 7 millimetres in thickness. In each experiment, the plate was wrapped in gummed paper, which prevented the separation of the fragments produced, since without this precaution, it would have been difficult to ascertain the disposition of the fractures.

Simultaneously with the rupture, fissures in great number are produced in these plates of glass. Notwithstanding their curves and inflections, the disposition of these fissures pre-

sents a geometrical regularity in its ensemble (fig. 1). This regularity is still more striking if viewed at a distance from the plate, or if, instead of considering the plate as unique, we examine a series, so as to take an average of the results. Notwithstanding the irregularities, we immediately discern the existence of two systems of directions, equally inclined on the axis of torsion. Radiated groups appear on each, in the form of sharp fans, the rays of which are respectively parallel to each other.

While the major part of the fractures traverse the entire plate, some lose themselves in the interior; others stop abruptly with conjugate figures, beyond which they do not extend, thus forming a series of truncated fragments in echelons, a disposition very frequently met with in nature.

1. The fissures in question consist of skew surfaces of varied form, the outlines of which on the large faces of the plate, which I shall designate *outcrops* (*affleurements*), are nearly in a straight line, and have an evident tendency to parallelism.

2. In addition to which, these fissures are grouped in accordance with two directions or systems, which may be qualified as conjugate, and thus constitute a net-work or reticulation (*réseau*) of which the lines are more or less close, according to the plates, and many crossings are perceived, forming lozenges.

The two conjugate systems generally cross each other at very open angles, the value of which appears to depend on the relative dimensions of the two sides of the plate, and this angle which is often nearly a right angle, in other cases in reduced to 70 degrees and even less.

3. The intersections or knots formed by the principal fissure of this reticulation have a tendency to distribute themselves according to right lines parallel to the long edges of the plate. In the conditions of this experiment, when these right lines are only two in number, they are usually at a short distance from the edges, and when the number is increased to three, one of them blends with the median line, and the two others are symmetrical in relation to it. The drawings in zigzag, corresponding to each of these two types, are very regular.

4. If we consider the manner in which the surface of each of these fissures is inclined on the large faces, we shall see that for one fissure the line of greatest slope is exceedingly variable, and in addition, that it varies in direction. These inflections are frequently met with in the faults. The inclination also varies considerably; it attains at least 50 degrees on each side of the perpendicular[1].

All these circumstances are found approximatively represented in a geometrical form, if we consider the surface of these fissures as a paraboloid or a skew plane.

5. A species of parallelism displays itself in certain groups of fissures, not only in their outlines, but also in their surfaces. A certain number of fissures, six, eight, or even more, participate in this parallelism as it occurs in nature.

6. On various plates, in the place of one fissure, a group has been formed resembling a fan partially opened; seve-

[1] Near the edges of the plate the fissure usually approaches the normal direction.

al may be seen which commence from a single point and re included in an angle of less than 20 degrees.

7. Among the fissures in question, there are a few that ave made a complete separation or a true fracture. There still adherence, for the most part; they are simple fissures resenting several types; sometimes they traverse the entire ngth of the plate, sometimes they are cut and deflected y other fissures, and only occupy a part of the plate, some- mes one of their extremities does not attain the edges of ie plate, or of another fissure, and loses itself in the mass; short, these fissures are entirely confined to the inte- ior, that is to say, they nowhere attain the surface of the late.

The fissures belonging to these various types, particu- rly the shortest and smallest, as also the fractures pro- erly so called, are subject to the general conditions of paral- lism before enunciated.

8. The examination of certain plates of glass will enable s to recognize straight lines on the surface, very fine, like hose of the burin, parallel and often more regular than the ssures.

They correspond to extremely fine cracks, and are visible hrough the medium of the reflection on their sides, as fre- uently occurs in certain crystals easily cleavable, or in cer- ain gems, in which they constitute flaws (*glaces*).

They indicate a kind of cleavage, the existence of which nay be immediately ascertained by a shock, which will hen make apparent, plane and parallel faces, usually per- endicular to the large faces of the plates.

Subjected to the action of polarized light, these incipient

fissures present signs of illumination at their edges, and particularly at their extremities, very clear and frequently very strong.

Fractures obtained by a simple pressure. —For practical purposes, stones are every day submitted to a strong pressure, and the operation of the ruptures is well known. Generally speaking, a stone cut in form of a cube, has a tendency to break pyramidally. Nevertheless stones called *hard*[1], may present fissures perpendicular to the plane of pressure, and often nearly parallel. But the degree of consistence of the mass has considerable influence on the results.

Bodies at the same time brittle and flexible, in the fractures they experience by slipping, appear to me to require the attention of the geologist.

Similarly, when it was a question of producing flexures, I experimented on substances of this character, in such a manner as to make the nearest possible approach to natural phenomena.

The mixtures employed were of plaster and beeswax, with a certain quantity of resin, constituting a substance analogous to that which is known as moulding mastic (*mastic à mouler*). Experiments were made by the aid of an hydraulic press, on the prisms formed of this mastic. Those with a square base, had been melted with great care, so as to be as homogeneous and as exempt from cavities as they could possibly be made; after the fusion, they were made smooth and regular by planing, in order that the faces should be

[1] The Cretaceous limestone of Cruas (Ardèche) may be placed in this category, as also the carboniferous limestones now worked.

perfectly rectangular; their dimensions were 14 centimetres square, by 30 to 33 centimetres in height. The plates of pressure were exactly the size of the base of the prisms, so

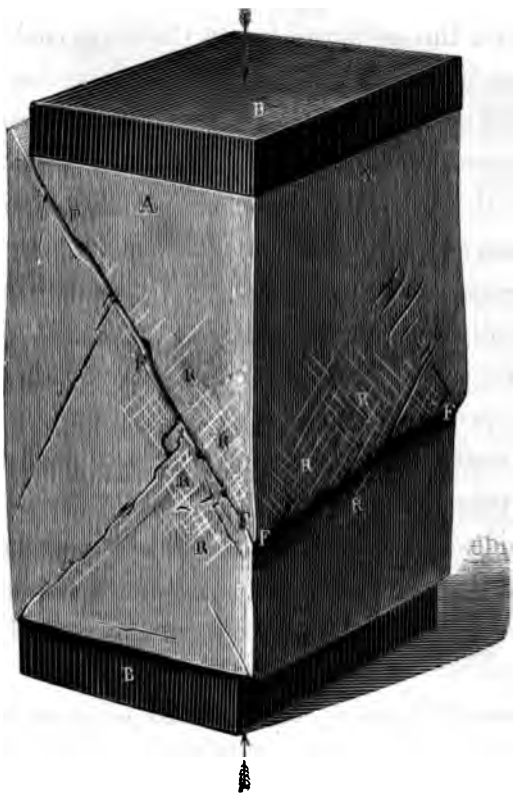


Fig. 2.— Prism of moulding wax subjected to hydraulic pressure in a vertical direction.

that certain displacements might be produced after the rupture.

1. Pressure very soon determines a cleavage almost plane, and oblique to the plates (fig. 2); the line of incidence does not deviate from the perpendicular more than 45 degrees.

This cleft, commencing from one of the upper horizontal edges, becomes gradually larger, until it attains the opposite face so as to detach a triangular prism. Then, a slipping movement is produced on the inclined plane which has just been formed, and this action of losing the level continues if the experiment is not stopped in order to examine the effects produced. The face of the rupture instead of being perfectly plane, presents some asperities, and these result in consequence of the rejection of the alternatives of dilation and compression, as is seen in the greater number of metalliferous veins. A second fracture (fig. 3), equally oblique and symmetrically placed, in relation to the first, is formed, commencing from the lower edge, and continues until it meets the preceding one.

Occasionally, ramifications or branches detach themselves from the principal clefts.

2. Besides the principal clefts, a numerous series of rectilinear and parallel fissures is observable on each face that has slightly convexed or bulged (fig. 2 and 3) in consequence of the yielding of the substance.

The fissures are very slight; many of them are only to be detected by lines so fine and regular, that they might have been traced by the burin.

These fissures are grouped in directions parallel to the principal clefts, and are nearly at right angles to each other, forming a close and compact reticulation. Whatever degree of fineness they may possess, they are always distinct, clear, and very numerous, since it is possible to count from 60 to 70 in each direction, in the space of 90 to 120 millimetres. Besides which, the magnifying glass enables us to

discern in the middle of the distinct fissures, very fine lines, exactly parallel to the first, and not less regular. The whole

Fig. 3. — Prism of moulding wax subjected to hydraulic pressure in a vertical direction.

recalls a check or stuff made of threads arranged in a rectangular form.

The mass, cracked in this manner has now become cleavable. While the principal clefts may be compared to the faults, the fissures more or less fine, may be assimilated

to faces of joint and cleavage, so frequently seen in rocks. The fine fissures disposed in system or reticulation result from a commencement of the yielding of the substance, and of the slidings which accompanied the deformations of the mass, however slight the latter may be. In certain parts, the division of the mass takes place in prismatic fragments possessing little power of adherence, and which, disintegrated according to the general alignments, are in a manner prepared for ultimate demolition.

3. Also the deformation gives rise to certain gaping rents or cracks which are attached by parallelism to the clefts and fissures simultaneously produced.

4. All these fissures of various orders are clearly grouped in accordance with two systems parallel to the principal clefts; they are inclined about 46 degrees in the direction of the pressure. As we have just seen, these two systems which are anti-parallel, have a manifest tendency to be perpendicular or orthogonal one to the other.

As fractures obtained by torsion, I shall designate them conjugate systems.

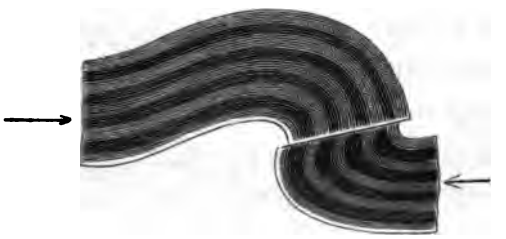
5. I only mention by way of note, a system of furrows produced nominally by pressure.

One of the systems of fractures may preponderate in relation to the other, and this predominance shows itself principally in the larger surfaces of rupture.

Fractures consecutive to flexures. — In various deformations, ruptures may not only be produced by extension, in the form of a V, but also by a slip.

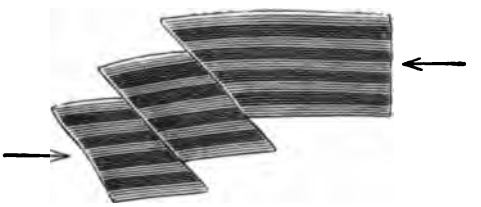
Prisms, the length of which considerably exceeds the

dth, being subjected to pressure in the direction of · length, inflect for some time, and occasionally break ;r the action of the same pressure, by the effect of a



. — Prism consisting of a series of layers of wax in different colours and sub- ɜd to pressures indicated by the arrows. Fracture produced with slip consecutive he inflection.

ɜcular slip. The rupture then follows a plane usually ɟue on the surface of the layers. Also, if the pressure is inued, it may occur that the two sides of the fracture slip one upon the other and become mutually striated,



›. — System of two faults produced on the prism of figure 4, parallel to each er, and equally consecutive to the inflection of the layers. In this instance, the ection of the outthrow is opposed to the action of gravity.

ɜmbling a fault. This movement of slipping, once com- ɪced, continues indefinitely, if the pressure caused by face of the rupture be persisted in (fig. 4 and 5).

DEDUCTIONS FROM THE EXPERIMENTS RELATING TO SUBTERRANEAN FRACTURES.

The results of the three series of experiments which precede, appear to have various geological applications, both in the subterranean fractures, and in the effects which result from them in respect to the topographical and geological relief of the ground, and probably the crevices of the glaciers; I shall add the following indications to those just pointed out.

Forms and dispositions of the faults. — Considered at different levels, in their horizontal outlines as also in their outcrops, the faults present configurations similar to those resulting from the experiments before described. By way of example, I shall mention the faults of the Côte-d'Or, which have been depicted with great care, both in plans and vertical sections, by M. Guillebot de Nerville; those of the Haute-Marne, by MM. Élie de Beaumont and de Chancourtois; also those delineated on various sheets of the geological chart of England, etc. These faults frequently present skew surfaces inflected like those resulting from torsion. A certain parallelism generally prevails in the groups of faults and lodes, not only in the outcrops, but also in the dips[1].

Forms and dispositions of the joints. — The joints display parallelism in a manner not less conspicuous.

[1] Lodes in Cornwall; lodes in the district of Maria-Adalbert at Pizibram (*Annales of the Mines*, 6th series, vol. XV, pl. III).

The vertical escarpments of the cliffs of Normandy, which attain a height of 100 metres, and are easily accessible at ebb-tide, afford singularly favourable opportunities for studying the joints.

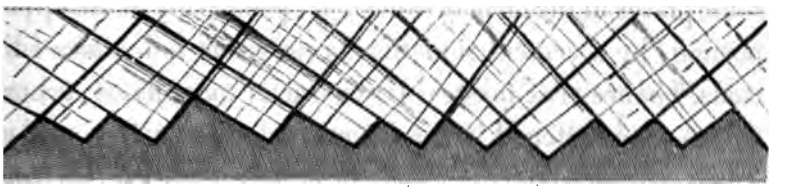


Fig. 6. — Detailed plan of the disposition of the joints traversing the Trépo.t cliffs, which serving as guides to the commencement of erosive action, have caused the formation of caverns near the level of the sea.

Owing to the destructive influences at work along the planes of the fractures, the joints are not merely visible on the vertical plane, but recognizable both in form and direction.

By carefully taking the compass bearings of all the joints clearly visible for a length of about 14 kilometres, from the Bourg d'Ault to Jolibois, near Mesnil-Val, varied directions

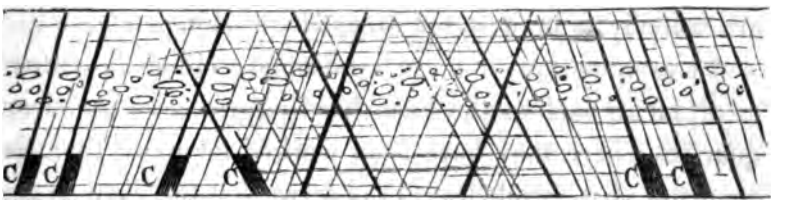


Fig. 7. — Detail in section of the joints represented in fig. 6.

are observed, in the midst of which there are two which predominate over the others; their averages are respectively N. 50° E. and N. 127° E. Considered thus, in horizontal plane and vertical section, these joints constitute two systems of which the ensemble gives the idea of a reticulation. Similarly,

in the environs of Fontainebleau, where the strata consist of Tertiary sand and strata of lacustrine limestone, some of which are below, and others above the sand. These sands are generally of an incoherent character, and are agglutinated in some places in the form of sandstone, principally in the upper portion, by a cement sometimes calcareous sometimes silicious. Thence arise masses of a character mamillated, tuberculous, and flattened in the direction of stratification, and of which the horizontal dimensions are considerably varied from a few metres, in this case forming *tables*, to several hundreds of metres in all directions, presenting, when the upper limestone is removed, rocky plateau designated *plattières*.

Wherever the sandstone crops up, it is traversed by joints or diaclases. The greater part of these are plane or slightly undulated, nearly vertical, and cut cleanly through the entire thickness of the sandstone. While some lose themselves at the distance of a few metres, in a horizontal direction, others continue, unchanged, for a distance of 80 à 100 metres and more. They are frequently so thin, that the edges are scarcely to be detected except by working.

An examination of these sandstones, either in natural escarpments such as the Franchard gorges, or in numerous quarries where they have been worked for more than five centuries, has enabled me to observe that the clearest and most extended joints present a certain constancy of direction, not only in the same quarry or group of quarries, but in the whole extent of the forest. This deduction is the result of several hundreds of measurements that I have taken on a superficies of about 180 square kilometres, the predominant direction varying between N. 95° E. and N. 118° E.

and averaging N. 118° E. A single diaclase deviates frequently from 15 to 20 degrees, even in the distance of 20 metres. These variations in an average are therefore easily explained, and it may be considered extraordinary that they are restricted to these limits.

Besides the principal diaclases (system A), there are others (system B) that are nearly perpendicular to them, and to which the workmen give the name of *cross joints*, in contrast to the first which they call *long joints*. The latter are less regular and more contorted than the former, which occasionally stop them; they are also less numerous, and their average direction is N. 12° E. While the mutual distance of the diaclases of the principal system hardly exceeds 4 or 6 and seldom attains 10 metres, those of the second system are often farther removed from each other. At some points, notably at the Long-Rocher and at the Rocher-du-Long-Boyau, they have a mutual distance of 70, 80 and 90 metres, which affords an opportunity of observing surfaces of vast extent which have been laid bare by working.

There are therefore two systems of diaclases, nearly perpendicular to each other.

If the constancy of direction which prevails in a vast extent of surface, be taken into consideration, then the diaclases of sandstone in the forest of Fontainebleau, cannot be recognized as the results of contraction. If this conclusion required corroboration, it would be afforded by the persistence of the same direction in the limestone beds in the immediate vicinity of the sandstone, a direction which thus shows itself independent of the mineralogical character of

In the same manner as the faults, which they resemble in parallelism, so the diaclases can only result from mechanical action exercised externally to the masses, and which has been produced, either when these masses were carried above the level of the sheet of water underneath they were deposited, or in more recent movements or settlements. It is in short, a system of fractures, similar, in disposition and origin, to those artificially obtainable in a plate by a slight torsion; the irregularities are of the same nature throughout.

The circumstance that in nature, the diaclases of one of the systems are frequently stopped by those of the principal system, is in no respect opposed to the supposition that they may be contemporary, or very nearly so; this is sufficiently imitated and explained by the experiments.

Probable frequency of the effects of torsion in nature. — From the preceding observations, it will be seen that a marked resemblance exists between the numerous fractures of various magnitudes, which traverse the terrestrial crust, and the fractures produced on thin plates by torsion. In the former as in the latter, a great number of rectilinear cleavages are observed, grouped parallel to each other; throughout, these series of parallel cleavages group themselves into two or more orientated systems, following different directions, in such a manner as to constitute reticulations. This resemblance in the effects, may justify the supposition that there is a certain analogy in the causes.

This approximation is attended with the more probability, inasmuch as we directly admit that the effects of tor-

ion may, and indeed must have been produced in the terestrial crust.

In the chapter where he has applied the mathematical heory of elasticity to the terrestrial crust, Lamé concludes hat this covering may have undergone some torsions under he simple action of strong interior pressure, of gravity and of external pressure [1].

Apart from mathematical considerations, the numberless leformations that have taken place in the terrestrial crust, luring vast periods of time, lead to the conclusion that torions must have operated in many parts.

Everywhere we find proofs of strong lateral or horizontal ressures, and except in rare and isolated cases, these pressures have doubtless not been able to operate with sufficient egularity to prevent the contrary forces, acting at the same ime, from producing torsions. This conclusion on the posibility of frequent torsions will receive additional confirnation from an examination of the various inflections and listorted forms observed in several coal basins in the centre of France, where the tendency of the strata has been exactly erified in working; for instance, in the basin of Saint-Étienne, in the environs of La Ricamarie, where, at some points, flexures have caused the disappearance of the parallelism of the strata; those of Creusot, of the Montreau and Montchanin (Saône-et-Loire), Commentry and Bezenet (Allier), Saint-Éloi (Puy-de-Dôme), Decazeville (Aveyron), the Pas-de-Calais, and many others display strata comprised

[1] For if we consider the forces in a vertical plane separating two masses, hese forces may constitute a traction in one part of the plane, and a pressure n the other.

between sinuous and uneven surfaces, often very irregular, and seams of coal called *en chapelet;* the expansion of these seams, separated from each other by nips (*étranglements*), appears to show the effects of torsion. The slate quarries in the vicinity of Fumay, for example, have brought to light equally complicated flexures.

In all parts, even in the regions where the strata appear plane, as in the North of France, there have been deflecting or warping forces in operation. In these various transformations, torsions have been produced, slight as they may appear, although they might have been caused by settlement alone or the canting caused by the action of gravity. In the latter case, much more than in that of violent dislocations and strong lateral thrusts, the outthrow of the faults must have been produced in the direction of the action of gravity.

In addition to which, and without having recourse to suppositions, there are numerous faults which have preserved the mark of a torsion not only in their skew forms, but also in the contrary nature of the outthrows that they have produced.

We see, in fact, the outthrow vary in amplitude for one side of the fault, when the line of direction is followed, and it is by no means rare to find that one of these inner sides has undergone, in one place a relative elevation, in another a depression. These faults with contrary outthrows (positive and negative) have an intermediary point or knot where the outthrow is null, so that miners in certain localities designate them under the name of « hinged faults » (*failles à charnières*).

Amongst the varied mechanical forces of nature, and the

lateral crushing to which the terrestrial crust has everywhere been subjected, experience leads us to the conclusion that torsion is one of the probable, if not certain causes of a mode of fracture widely diffused, notably in the joints and faults. It is a fact which experiment brings to our aid, in the solution of the general problem.

Fitness of special denominations for various orders of fractures. — Among the fractures of varied forms and origins, which traverse the terrestrial crust in every direction, there are certain types that it appears useful to characterize and coordinate in a distinct manner.

Some of them have been produced by contraction; these are the prisms well known in volcanic rocks. Others have planes of *cleavage* of a schistose character, which will be mentioned later.

But the most important of the fractures appear to be owing to a molecular sliding or slip, and are incident to *pressures*, the first cause of which must be sought outside the rock itself; these latter fractures are of the nature of those that have left deep impressions in the flexures of the stratified rocks, and the faults of which are the best known representatives.

These fractures have generally received the name of *joints*, which appellation has been also adopted by English geologists[1], and I have made use of the term in the preceding pages. This name is borrowed from architecture, in which it designates the planes in accordance with which the courses of a building are assembled, and on the other hand

[1] In German, *Klufte*, *Risse*, *Spalte*, *Absonderungsfläche*.

appears incorrect, when it concerns faces of rupture, to which the name of *disjoint* would be more properly adapted. We may substitute for it a name at once more suitable and more comprehensible in different languages, viz. that of *diaclase*[1].

The intimate and original relation characterizing the numerous facts which unite the joints and faults, and which belongs equally to the domain of observation and experiment, forms an inducement to recall their common origin by a similitude of name.

That of *paraclase*[2] indicates that the fracture is accompanied by a displacement. Without pretending to substitute it for that of *fault*[3], which is so widely diffused, I think it right to present this appellation to the attention of geologists, for the twofold reason that it possesses a direct relation to the name *diaclase*, and that the etymology is perfectly rational.

In brief, the diaclases and paraclases constitute two great groups in the fractures which now occupy our attention, to which the general name of *lithoclase* would be suitable.

APPLICATION OF THE EXPERIMENTAL METHOD TO THE STUDY OF THE CHARACTERS OF VARIOUS ORDERS PRESENTED BY THE RELIEF OF THE GROUND.

The fundamental influence that the geological constitution exercises on the configuration of the surface of th

[1] From διά (across or through), mark of division, and κλάω (to break to divide), fissure made by breaking.

[2] From παρά, a preposition usually expressing *obliquity, laterality,* a κλάω. The word applies well to a fissure accompanied by a lowering of o of the sides in relation to the other, which happens in the faults.

[3] In English *fault;* in German, *Verwerfung, Verwerfungsspalte, Sprung.*

ground is everywhere manifested, whether we consider the great masses in the ensemble of their arrangement, or analyze the details of their forms. Without the knowledge afforded by the science of geology, it is not more possible to understand the contour and relief of continents, than to appreciate many of their topographical characters.

But if the differences presented by the masses of rocks in their mineralogical nature, as well as in their original juxtaposition, have a large share in the physiognomy of each region, the action to which these rocks were submitted, after their formation, plays also an important part.

This posterior action, though of a complex nature, may be summed up as fractures and erosions.

Well known influence of the paraclases on the relief of the surface. — In respect to the faults properly so called or paraclases, the influence they exercise on the general shape of the surface is well known, and the geologist frequently recognizes it in the anomalies they cause in the relief.

The paraclases often present themselves on the surface in abrupt and extended projections, comparable to cliffs; such are those which terminate the chain of the Vosges, on the side of the plain of the Rhine, particularly in the northern region, formed of Vosges sandstone, or that which bounds the Wurtemberg Alps. Sometimes the faults give rise to abrupt projections, which, though not so extensive as those just cited, are sufficiently well marked (Côte-d'Or, where they are known by the name of hedgehogs, *hérissons*). These projections, of different degrees of importance, are caused

by the outthrows more or less considerable, which have imparted to one of the sides of the fault a relative elevation which still exists, at least partly, where the posterior erosions have not caused it to disappear.

Paraclases are frequently recognized, not by their projections, but on the contrary by the erosions they have caused. Long ago, la Bèche showed that, in the district of the Black-Downs, faults which traverse the Cretaceous strata have caused the formation of valleys[1]. In pointing out the parallelisme of the Lys, Escaut, Dendre, Senne, Dyle and Gete, d'Omalius also supposed that these lines were the result of fractures, as Dumont had arrived at the same conclusion with regard to the Hesbaye. Many of the coal fields, where the working renders it imperative to follow and mark out accurately the position of the faults, offer analogous coincidences; as those of Saint-Étienne, Blanzy, the Grand' Combe and Bessèges, where the faults announce themselves by numerous valleys. This fact is too well known to need the citation of other examples. The name of valleys of faults (*vallées de failles*) adopted by d'Omalius[2], is therefore frequently justified.

In all the cases just mentioned, it often occurs that the erosions have a tendency to efface the character of the original fractures, on which they are in some measure grafted, since they appear to have substituted for them their own serpentine forms. But even though the lithoclases have produced no outthrow, that is to say when they do not belong to the category of faults properly so called or para-

[1] *Researches in Theoretical Geology*, p. 185 and 186, 1836.

[2] D'Omalius, *Précis élém. de géologie*, p. 452.

clases, the fractures or diaclases of the rocks appear to have played an important part in the model of the surface.

In the first place, the fact can be established on a small scale and on various rocks, by studying the projections they frequently form. Thus in the sandstone of the Vosges, we meet with isolated rocks in form of parallelopipedons, and escarped cornices resembling strong castles. The same fact occurs in the Quadersandstein of the Saxon Switzerland and of Bohemia, the stratification of which is also horizontal and cut by vertical slopes, often nearly at right angles to each other, whence results the division into parallelopipedons to which the name [1] is due.

The same fact may be demonstrated by examining the « seas of rocks » (*felsenmeere*), which are met with in formations very coherent and of various characters; granite (Brochen, Odenwald); Vosges sandstone (plateau of Sainte-Odille, Menelstein, Ungersberg); variously coloured sandstones (environs of Plombières, where they are known under the name of *meurgers*).

The fragmentary and ruined state of high summits appears to be a general fact. Thus, the Pyrenean peaks consist for the most part of heaps of blocks, frequently designated as chaos, in the same manner as the summit of Mont Perdu, the rocks of which were so attentively studied in all their forms by Ramond.

The topographical influence of the diaclases is everywhere manifested on a much larger scale. The more carefully we study on exact charts, the general outline of valleys

[1] Naumann, *Erläuterungen*, n° 3, p. 49.

and the relief of the surface, the more fully we recognize on all sides, even in countries where the strata are nearly horizontal, numerous features rectilinear, parallel, and often bent. Colonel Goulier of the engineers, one of our most learned topographers, has called attention to this fact, which frequently shows itself in relation with the diaclases.

Light thrown by experiments on the cause of these various topographical features. — Experiments furnish data which rapidly throw light upon the positive results due to the observation of natural facts.

In our experiments, we have in fact produced some series of parallel fractures, grouped in systems possessing different orientations, and often perpendicular to each other. We see also forms kneed or in zigzag, originated by the intersection of two of these systems of fractures. They are therefore dispositions quite analogous to those presented so frequently by the forms of relief.

It is important in this place to make two observations on this similarity. On the one hand, the diaclases have been only partially denuded, that is to say on a small part of the outcrops; on the other hand, as we mentioned in respect to the faults, the erosive agents have left their impress and characteristic sinuosities in the regions exposed to their attacks, and this in the following manner; as soon as certain gutters were excavated or worn, they became the principal arteries, and attracted the water which was to hollow them out still more, according to laws entirely different from those which had influenced the fractures. This second and preponderating effort of displacement caused the disappe-

rance of the original character of the fractures. For the double movement, this character shows itself in a very incomplete and often deceptive manner; nevertheless in certain places, it manifests itself very significantly. Though often very delicate and in so small a minority, that they might pass unperceived, these features testify to the influence of the fractures.

From the preceding observations, we obtain an explanation of the various types of a model very widely diffused, which the erosive action of water, however powerful, cannot explain, and which are met with in the stratified formations in which the strata have remained horizontal, as in the regions where dislocation has taken place. Such are the series of parallel features repeated on all sides, by grouping themselves under several distinct orientations, as we have just seen; some are observed as being only in a state of commencement.

To this reticulated system are incident the abrupt and frequently rectangular knees, which are observed in a great number of valleys. The outline of these valleys considered horizontally, offers a succession of forms in zigzag and pothook, so that it is not always easy to distinguish the sinusoidal forms, that the watercourses have excavated in the movable alluvion constituting the bottom. The kneed forms have besides their analogies in chains of mountains, where the disposition of valleys has long been remarked to be nearly orthogonal; some longitudinal, others transversal or forming *cluses*, as also abrupt elbows such as those of the Rhône at Martigny.

It frequently occurs, that several disrupted valleys form

themselves in the same straight line, and reappear successively, notwithstanding the intermediate prominences separating them, and thus appear as different portions of one rectilinear fracture.

However powerfully the erosive action may have operated, in the process of excavation, it has not succeeded in delineating the first outline of these different types of form. As may be seen, such a configuration is analogous to the reticulation of fractures without outthrow, which result from the experiments before mentioned, and which always accompany the fractures with outthrow, these latter being much less numerous than the former, and equally attributable to a molecular slip.

Owing to their great number, the joints or diaclases have materially contributed to erosive action, thus rivalling the faults or paraclases.

In the fractures obtained by pressure, we have seen that the cleavages and rents are multiplied in accordance with certain alignments, in such a manner as to isolate numerous prismatic portions, and the parts thus disintegrated would, under certain conditions, be in an extremely favourable state for demolition. It is an experimental result which appropriately connects the natural facts just stated.

Some of the experiments reproduce, in their details, valleys called valleys of fracture or displacement. Some of these are only fissures but partially opened, such as those of the Tamina, Trient and the Via Mala (Switzerland), the Fier (Savoy), the place where the Rhône disappears near Bellegarde, the *ruz* and *cluses* of the Jura, the Rummel near Constantine, the canons of Wisconsin and

e Colorado[1]. Without possessing the same characteristics, great number of valleys belong to the same type; such the abrupt valleys of the Jurassic *causses* of the South France, those that cut into the vertical strata of mo-sse, as the Vevèze near Vevey and the valley of Chaudron ar Montreux. When the sides of these valleys display arcely any traces of erosive action, and the bottom shows e solid rock, instead of being filled up by debris, we are d to conclude that these valleys result from fractures that ave remained permanently open.

The blocks of mastic subjected to pressure show rents hich closely resemble the valleys in question. Here and here their fissures are abruptly inflected, once or several imes, and nearly at a right angle. The kneed disposition esults from the tendency to unite with the fractures suc-essively. The clefts in particular, appear on the surface f the blocks where the pressure was less than in the nterior.

In addition to which, prisms of substances simultaneously lexible and brittle, can, when bent, be at the same time torn n a gradual manner. If the convex part, which breaks by extension, be turned upwards, the rent descends at the same time that it contracts, while in its horizontal projec-tion, it presents a serpentine or zigzag configuration. An iron prism tears in a similar manner, and this recalls more particularly the valleys called valleys of upheaval (*soulève-ment*), of which Pyrmont affords a classic type. All des-criptions of intermediaries connect these valleys or ravines

[1] This type has been designated by M. Desor under the generic appellation of *Rafla*.

of separation with valleys more widely opened, that are frequently found, even outside the mountain ranges.

If we operate on the alternations of brittle and plastic layers, we shall succeed in imitating other natural effects, for instance, the ruptures produced at the culminating portion of the Jurassic vaults, as also the crests which surround them.

Summary. — When we study the constitution of a district, especially when it is mountainous, we endeavour to seek out and coordinate the principal projections, such as summit lines. But the prominences originally existing, have in general been considerably shattered and in some cases entirely destroyed. In the Alps and elsewhere, the lofty summits and most salient prominences that remain, represent but fragments of the primitive mass; scattered ruins, resulting from irregular and as it were accidental demolition. The knowledge of the structure of a district is augmented by investigating the interior lines of fractures, paraclases and diaclases, which are without doubt, less apparent, but which have not been acted upon by the same destructive agency.

The immense power with which streams of water, snows, and glaciers have acted upon vast regions of continents, particularly during the period called Quaternary, is incontestable; the force displayed is a subject of astonishment, and this doubtless explains the fact that its effects have often been exaggerated. For the fractures produced by the deformation of the soil, had prepared those considerable erosions, and cleared the way for them; in disintegrating the rock, they had formed the outline of the actual

model. Though much changed by such enlargements, the original disposition of these fractures reveals itself to the attentive observer. These characters testify to the priority and to the action, partly *directive*, of the fractures that furrow the substrata. Everywhere, even in the countries where the strata have to a great extent retained their horizontality, the relief of the surface presents the reflex of numberless internal fractures, encountering and repelling each other in significant outlines.

In any case, it is incontestable that orographic features of various characters are faithfully reproduced in fractures obtained artificially by simple mechanical action, pressure or torsion, in the same manner that they have been frequently produced in the terrestrial crust. It may also be inferred, that in the one case as in the other, in nature as in experiments, perturbations of the same character are observed in juxtaposition with a manifest tendency to similar forms of geometrical regularity. In like manner, experimentation appears to throw some light, not only on the history of the faults and joints, but also on different characteristics of a geographical and topographical nature.

XLVII

QUESTIONS OF SYNTHETICAL GEOLOGY.

Under this title are collected four series of surveys, documents and models, relating to some parts of the synthetical generalities of the geological lectures at the « School of Mines ».

A. UNIFICATION OF GEOGRAPHICAL AND GEOLOGICAL WORKS.

B. GEOMETRY OF THE PENTAGONAL « RÉSEAU » AND GRAPHIC SPHERODESY.

C. SURVEY OF GEOLOGICAL ALIGNMENTS AND APPLICATION OF THE PENTAGONAL « RÉSEAU ».

D. IMITATION OF OROGRAPHIC ACCIDENTS OF UPHEAVAL.

Collections of documents, dissertations, notices and numerical tables (large and small volumes bound).

Chart of the survey on the 80 000th (with case).

Planisphere with text and gnomonic maps, plane draughts, compass, graphic surveys of alignments, tables, heliographic plates, photographs (panel and portfolio).

Geographical globe and octahedron, series of conjugate solids, spherical draughts (models).

A. UNIFICATION OF THE GEOGRAPHICAL AND GEOLOGICAL WORKS.

a. *Documents and dissertations, collected on account of the meeting of the Congress of Geographical Science in Paris, 1875.*

Collection (8vo) comprising :

1° PROGRAMME OF A SYSTEM OF GEOGRAPHY based on the use of the decimal measures, of an international grade O meridian, and of stereographic and gnomonic projections. (Presented to the *Academy of Sciences*, 23rd March 1874. — Extracted from the *Report of the Geographical Society*, Septembre 1874.)

2° CHART OF THE GLOBE IN GNOMONIC PROJECTION. Explanatory notice ith specimen sheet, engraved. (Presented to the *Academy of Sciences*, d November 1873. — *Report of the Geographical Society*, March 1874.)

3° THE SYSTEM OF THE DETAILED GEOLOGICAL CHART OF FRANCE, pre-nted as a base of discussion for the establishment of a programme esolving the question of the UNIFORM EXECUTION OF GEOLOGICAL SURVEYS. Extracted from the *Report of the Geographical Society*, January 1875.)

4° Note on the detailed geological chart of France. HISTORY AND EFINITION OF THE WORK, with reduced table of the collection. (Re-production of the *Preface sheet* B, extracted from the *Annals of the Mines*, 7th series, vol. IV, 1873. — With a list of the 42 first articles of the publication offered for sale in 1874, M. Élie de Beaumont being Director, and M. Béguyer de Chancourtois, sub-director of the service.)

5° GENERAL TECHNICAL EXPLANATORY DESCRIPTION of the detailed geological chart of France. (Reproduction of the *Sheet of generalities* C, extracted from the *Annals of the Mines*, 7th series, vol. V, 1874.)

6° Detailed Geological Chart of France. SYSTEM AND METHOD OF APPLYING THE GENERAL GEOLOGICAL DESCRIPTION, with tables of lithology and stratigraphy, and specimens or elements of the tables of geognostic chronology. (Reproduction of the *Sheet of generalities* D, extracted from the Annals of the Mines, 7th series, t. V, 1874.)

7° ON THE REGULATION OF GEOLOGICAL RESEARCHES, OF THE ASSOCIATION OF STUDIES OF GEOLOGY, HYDROLOGY, AND METEOROLOGY, AND THE INSTITUTION OF A TOPOGRAPHICAL AND PHYSICAL ABSTRACT OF THE TERRITORY IN UNIFORM DETAIL ON A CADASTRAL SCALE OF THE $\frac{1}{10\,000}$th, with a synoptic table of the divisions of geology, arranged recording to a general classification of the sciences. (Paper presented to the *Geological Society*, 29th March 1873.)

This collection was formed by M. B. de Chancourtois, author of Nos 1, 2, 3 and 7. In addition to the specimens of the system of geography, the photograph N° 1 represents

the means and results of the survey of geological alignments exhibited at the same time, in 1865. (See D.)

b. *Documents collected in one volume (with engravings and tables), after the Geological Congress of Paris in 1878.*

This volume (large 8vo) comprises :

1° *Lecture on the unification of geographical studies*, delivered on the 3rd September 1878 at the Trocadero Palace by M. B. de Chancourtois. (Extracted from the *shorthand reports of the congresses and lectures that took place during the Universal Exhibition of 1878*, published under the direction of M. Thirion, by the Ministry of Agriculture and Commerce; National Press, 1879, with bibliographic plate.) (See hereafter C.)

2° *Transcription of geographical names in letters of the Latin alphabet.* A paper of M. B. de Chancourtois (extracted from the *shorthand reports of the second International Congress of Geographical Science, held in Paris in 1875*, published in 1878, under the auspices of the *Geographical Society of Paris*) with table of *classification of the 21 letters of the Latin-French alphabet, representing the simple phonetic elements.*

3° *On the unification of geological works in general, and particularly of those which refer to conventional figures (outlines, notations, signs, colours)* by M. B. de Chancourtois. (Extracted from the *shorthand reports of the first International Congress of Geology held in Paris in 1878.* Published at the National Press in 1880.) The subjects of this communication are in course of examination by two international commissions appointed by the Congress of 1878, to prepare the deliberations on the questions of unification placed first in the order of the day of the second Congress, which will meet in 1881.

c. *Programme of a system of geography based upon the use of the decimal measures of an international meridian* O *grade, and of stereographic and gnomonic projections.*

Heliographic reduction, on a tenth, of the Exhibition in 1878 in the Champ de Mars, class XVI, in support of the system.

The *explanation of the plate* (exhibited in the panel) is given in the following enumeration of *documents, charts, plates, globes, models and instruments which are there represented.*

1. Programme with notices of the system. (Extracted from the *Reports of the Academy of Sciences*, 23ᵐᵉ March 1874.)
2. Atlas of the whole. — Summary planisphere.
3. Atlas of the whole. — Specimen outlines of the four kinds of pages of the atlas 4to corresponding to the globe reduced to a hundred millionth: S, hemisphere of the stereographic series; O, triangle of the octahedral gnomonic series; C, square of the cubic gnomonic series; D, lozenge of the dodecahedral gnomonic series. — Sketches of the complete series, each grouped in a plate (size, quarter, double-elephant): S′, the six imbricated hemispheres determined by the planes of the meridian 0^g—200^g, of the meridian 100^g—300^g and of the equator; O′, development of the octahedron (octo-planisphere); C′, development of the cube; D′, development of the rhombododecahedron.
4. Atlas of detail. — Compendious planisphere.
5. Atlas of detail corresponding to the globe reduced to a scale of one millionth. — Minute specimen of a trapezium of the similar series. Chart in gnomonic projection of the region principally occupied by France. (Map size.)
6. Frame of repertory of geographical situations, with compendious indications of a classification of the altitudes and a system of methodical outline of curves of level for the figure of the relief.
7. Reports on decimal and duodecimal clock dials.
8. Classification of the letters of the French alphabet, presented to the Geographica Congress of 1875 for the transcription of geographical names.
9. Globe reduced to the hundred millionth with duodecimal plan.
10. Globe reduced to the hundred millionth with decimal plan.
11. Spherodesical instruments: ruler, square and compasses adapted to this globe (radius = $0^m,0637$).
12. Models showing the characters of the stereographic projections executed on a meridian
13. and an equatorial plane.
14. Model showing the characters of the gnomonic projections and the relations of the polyhedrons circumscribed on the globe which serve to establish the series: 1° conjugate octahedron, cube and rhombododecahedron; 2. imbricated polytrapezohedrons and polyrhombohedrons.
15. Model showing the imbricated disposition of the hemispheres of the stereographic series.
16. Octahedrons ..... } conjugate, circumscribed on the globe reduced to the hun-
17. Cubes ..... } dred millionth, presenting in gnomonic projection the deci-
18. Rhombododecahedrons } mal plan and the design of the geographical figure.
19. Transit compass, showing simultaneously the reading of the orientations in decimal and duodecimal measures.
20. Calculating tables for the conversion of duodecimal into decimal measures.

Notwithstanding the reduction to so small a scale, Nᵒˢ 2 and 3

sufficiently demonstrate the advantages of the meridian taken as an initial, meridian or O grade; it will be seen that this meridian is almost exclusively maritime, as it is situated in longitude 28°, 30 West of Paris and may be called the meridian of Saint Michael, since it passes near the island of that name; it leaves to the East all the islands adjacent to Africa, as well as Iceland, and only crosses the uninhabited or least inhabited parts of Greenland and continental Asia; afterwards, it leaves the Archipelagos of Polynesia, properly so called, to the East, and passes the Australian continent without touching it. The division produced by the meridian distant 100 grades or 90 degrees from this initial meridian, is equally advantageous for the settlement of the meridian limits of the hemispheres of the stereographic maps of the world, as for the distribution of the land in an octoplanisphere. The division by the meridian of the island of Ferro in the construction of the planisphere (D *d*), in which the duodecimal graduation was retained, was only adopted for the purpose of bringing it into immediate use, by showing all due consideration towards the method previously employed.

N° 3 shows that, for a chart on a scale of one millionth, of so extensive a region, the gnomonic projection which gives the outline of any great circle strictly rectilinear and consequently permits the alignments to be examined with the rule, does not produce to any appreciable extent more deformation than any other more complicated transformation of the spherical surface into a plane surface. The reproduction of this chart, the orography of which was shaded with the pencil, gives an idea of the advantages derivable from heliography, in respect of popularizing geographical knowledge by maps in relief, since the publication of these maps may almost immediately follow the execution of the map itself.

The system of geography which constitutes the subject of the heliographic plate now exhibited, was presented in 1874 to the Academy of Sciences (*Reports*) and the Geographical Society of Paris (*Report*). (See a' 1.) It was discussed at the second Congress of Geographical science in 1875, and furnished the subject of the conference of 1878 (See D b 1) and will be developed at the third Congress of Geographical science, which is to be held in Venice in 1881.

B. GEOMETRY OF THE PENTAGONAL « RÉSEAU » AND GRAPHIC SPHERODESY.

The geometry of the pentagonal « réseau » being susceptible of application, irrespectively of geology, a separate collection has been made of the models, maps and papers intended to popularize the knowledge of it, as also the method of drawing on a sphere. Although these subjects are combined for the study of the « réseau » and of the geological alignments, they have themselves a more general range.

a. *Directions for the practice of geometrical drawing on the sphere, and for its application to geography and geology*, by M. B. de Chancourtois (Extracted from the *Annales des Mines*, 1875).

b. *Sphere in stucco* representing the terrestrial globe reduced to the 100 000 000th. (See d, e.)

Radius = 0^m,0637; circumference = 0^m,4; a degree = 0^m,0011; a grade = 0^m,001.

c. *Spherodesic instruments* adapted to the preceding sphere. Rule (great circle); square (bi-rectangular triangle); compasses (beam compasses). (See photographed figures d, e, 11°).

d. *Spherical draught of the geodesic decimal survey*, showing the meridians and parallels at every 10 grades.

e. *Spherical draught of the pentagonal « réseau »*, comprising the plan of the 121 principal circles; regularly coloured, viz. the 15 primitive or hexahedral, the 10 octahedral, the 6 regular dodecahedral, the 30 rhomboidal dodecahedral, the 30 diagonal bisecting and the 30 diametral bisecting.

f. *Models showing the relations of the regular solids with the pentagonal « réseau »*.

1. Sphere containing the fifteen primitive circles, the 10 octahedral, the 6 regular dodecahedral and an example of each of the three last categories of principal circles, surmounted by a geographical globe prepared by M. Périgot, and bearing the same design.

2. Regular icosahedron surmounted by the star-shaped solid, formed by the 5 regular octahedrons which are described on it, and the edges of which correspond to the primitive circles.

3. Regular dodecahedron (conjugate with the icosahedron) surmounted by the star-shaped solid, formed by the 5 cubes (conjugate with the 5 octahedrons) which are inscribed into it.

4. Semi-regular triacontahedron (conjugate at the same time with the icosahedron and the dodecahedron) surmounted by the star-shaped solid, formed by the 5 semi-regular rhomboidal dodecahedrons (conjugate at the same time with the 5 octahedrons and the 5 cubes) which are inscribed into it.

The pairs of spheres or solids, are fixed on two rods which represent the axis of the terrestrial poles, so that, for each pair, the summits H, I, D of the triangle which comprises the North pole are projected on the points of the plateau of the base marked with the same letters, and it is sufficient to give to the four triangles of the plateaux the same orientation in order to render all the relations manifest at a glance. But it is important to notice that the colouring intended to bring out into contrast the relations of the five series of solids, is independent of the methodical colouring of the draught of the «réseau», and is only repeated on the sphere, when placed in juxta-position with three solids, by fringes which border the primitive circles.

g. *Plane draught* entitled the PENTAGONAL «RÉSEAU», *summing up the relations of the five regular solids, established in geology as the principle of coordination of the systems of mountains and of other facts of alignment, by M.* ÉLIE DE BEAUMONT, 1850.

This plate, which was executed at the National Press in 1874, and reproduced with modifications in 1878, presents, with an explanation in detail, the orthogonal projection of the «réseau», on the plane of one of the primitive circles and its gnomonic projection, for the quarter of the sphere, on the tangential plane which is the horizon of the centre of a pentagon. It corresponds to the spherical draught (e) in dimensions, notations and colouring.

h. *Applications of the preceding plane draught.* Examples of geometrical itineraries of circles of which the poles are given, traced by reflection in a single pentagon.

i. *Notice* entitled : *On the Pentagonal « Réseau » of M. Élie de Beaumont.* (Extracted from the report of the Geological Society, 1875), quoted here as giving a concise description of the « réseau ».

C. STUDY OF THE GEOLOGICAL ALIGNMENTS AND APPLICATION OF THE PENTAGONAL « RÉSEAU ».

Stratigraphy is the geometrical part of geology. As the etymology of the word indicates, the primary object was the study of the surfaces of those divisions of the earth's crust which are nearly horizontal, and of which the formation results specially from sedimentary phenomena; but at the present time it includes the study of surfaces nearly vertical and which are rather the results of movements of the crust and eruptive phenomena. These two subjects of consideration, though essentially connected, may be designated, in condensed language, by the terms *horizontal stratigraphy* and *vertical stratigraphy.*

The importance of the latter is not less striking than that of the former, in a practical as well as in a theoretical point of view, since divisional surfaces approaching the vertical, comprise metallic lodes and faults.

It is based upon the study of the geological alignments, and is pursued from the most recently established data which have immediate reference to the working of mineral deposits, as far as the entire collection of facts constituting the theory of the distribution of these deposits, and the general dispositions of masses of minerals whether eruptive or sedimentary. Moreover, in all degrees, these facts are shown to be in relation with orographic or hydrographic phenomena.

It may therefore be useful to present, in a collected form, the methods adopted by the « School of Mines » for this study of the phenomena of alignments, and the results of the application of the various orders.

The systemization of the alignments by the pentagonal « réseau »

(the geometrical properties of which form the subject of paragraph A) is found to be advantageous in the results as well as in the means of study, though these are, in several particulars, completely independent of each other.

METHODS OF STUDY.

a. *Tables of the numerical data fixing the circles and points of the pentagonal « réseau »*, published by M. Élie de Beaumont in the Transactions of the Academy of Sciences, 1863 and 1866.

b. *Notice* entitled : *On the pentagonal « réseau » of M. Élie de Beaumont*, by M. B. de Chancourtois. (Extracted from the *Report of the Geological Society*, 1875. — Already mentioned A k.

c. *Globe on the* 100 000 000th, *on which the 31 first principal circles of the pentagonal « réseau »* traced with spherodesic instruments (see A c) and by means of the numerical data of the tables.

d. *Octo-planisphere gnomonic. Chart of the globe delineated in gnomonic projection on the eight faces of a regular circumscribed octahedron*, of which the eight triangles juxtaposed show the development, with the indication of the principal points of the pentagonal « réseau », which mark out the rectilinear plan of this « réseau », constructed for the *study of the geographic alignments* in general, by M. *B. de Chancourtois*.

The globe to which this chart corresponds is the reduction of the terrestrial globe to the 100 000 000th. One of the axes of the octahedron is adjusted in coincidence with the axis of the poles, and two of the edges correspond to the meridian of the island of Ferro.

By the gnomonic principle of projection, the great circles of alignments are represented by straight lines, but these, in their development, necessarily assume the form of a polygon. An accessory plate furnishes the means of constructing the polygon, determined by a first side, or by two points belonging to two different faces, and the constructions or calculations necessary for the solution of the two questions are explained in the text.

The annexed plate presents, in addition, the outline of the pentagonal « réseau », and the text gives also the data and explanations essential to the study and utilization of the « réseau », having previously

shown the conditions under which the two plates are executed, and the manner in which the alignments may be followed, *irrespectively of all systemization.*

The text is completed by bibliographical references, information and desiderata referring to the use of the gnonomic charts.

The portfolio of the octoplanisphere is accompanied by an octahedron, formed with the plate of the geographical figure, and which may be substituted for a globe.

e. *The European pentagon in gnomonic projection on the horizon of its centre.*

Chart of Europe and the adjacent regions, published by M. Élie de Beaumont, with his notice on the systems of mountains (1852). — Enlarged by photography in order to correspond to the globe reduced to the 20 000 000th (See h, farther on).

f. *Engraved protractor, arranged to establish the bearings (roses) which form a summary of the local studies of the phenomena of alignments.*

This semicircular protractor is denominated transitory, because it shows, upon two concentric limbs, the decimal and duodecimal graduation. The circumference is divided decimally, and has a radius of $0^{m},0637$, or the 100 000 000th of the terrestrial radius; the length of the grade is therefore $0^{m},001$.

Two zones are reserved inside each limb, for the purpose of receiving separately the directions of the alignment taken and those of the classified circles, as deduced from calculation, the conjunction of which enables the relations to be appreciated. A zone contiguous to each limb is prepared for the reception of the value of the orientation, that is to say, of the angle of orientation of each bearing measured, commencing from the North by the East. Three exterior zones are intended to designate the classified circles of comparison. In the first, the poles and circles are indicated, and in the second, the principal points of the itinerary followed in a quadrant, by means of spherodesic notations taken from the tables of numerical data or from the octoplanisphere (d). The last receives the geographical or geological denominations.

STUDY OF THE WHOLE SUBJECT.

g. *Application of the pentagonal «réseau» to the coordination of petroleum springs und bituminous deposits; extended to the coordination of the points or lines of eruption and emanation, and to mineral lodes in general.* A paper of M. B. DE CHANCOURTOIS. (Extracted from the *Reports of the Academy of Sciences*, 1863.)

One of the conclusions of this paper is, that the alignments are grouped on the globe, in *systems of great conjugate circles*, each determined by one *great normal circle*, *common to the system.*

In consequence of this conclusion, and for the investigation and verification of the systems of alignments conjugate by a *normal*, an armillary with cupolas has been arranged, which enables a geographical globe to revolve round the axis of the poles of a given normal, and to bring this axis in the plane of the horizontal limb, to the level of which, the rotation of the globe then presents successively all the alignments of the system upon which the experiment is made. This apparatus was shown at the Exhibition in 1878, but it has not been possible to send it to the Melbourne Exhibition.

h. *Study of the general geological and geographical alignments on the gnomonic octoplanisphere.* (See B d.)

The alignments described in the above-mentioned paper, are traced on the different copies of this chart, viz.: 1. The two systems of circles having for their normals the primitive circle of the Rhine and the bisecting circle of Bassorah, and forming a square in the centre of the European pentagon; 2. the two systems of circles which have for normals, the trapezohedral of Tanganjika and the diametral of the lower Loire, also forming a square; 3. the system having for its normal the regular dodecahedral of Singapore, at the same time perpendicular to the normals of the two preceding systems, and forming with them trirectangular triangles; 4. alignments not systematized.

The peculiarly remarkable terms of the *system of great circles having for its normal the primitive of the Rhine*, are: the Pyrenean circle of comparison which passes by Etna, where its direction is found in the principal accidents of the Val del Bove, and the pencils of the lines

of fracture, and which may be traced from the petroleum beds of Bakou, at the extremity of the Caucasus, to the beds of the Ohio region, and from the mouths of the Volga to the mouths of the Mississippi. (For fuller information see note l.)

i. *Study of the general geological and geographical alignments on the gnomonic chart of the European pentagon.*

The systems of alignments figured on this chart, are the same as those on the octoplanisphere.

Among the alignments of the systems, the normals of which are the circles of Tanganjika and the lower Loire, the first to be remarked, is the circle which, passing by Etna and the Dardanelles, marks the southern limit of the Atlas mountains, the pencil which joins the quicksilver beds of Almaden and Idria and the circle which passing by the Côte-d'Or and the marshes of Pinsk, assumes an anticlinal character in the plains of Russia by turning the Volga; the second is the circle following the Gironde and the sea-coast, that which embraces London, Paris and Lyon; that which commencing from Etna, follows the course of the Rhine below Coblentz; and that which after pursuing the course of the Pruth, takes the embouchure of the Bosphorus and the head of the Nile delta. (For fuller particulars see note 1.)

j. *Studies of geological and geographical alignments as displayed on the geological chart of France.*

The systems af alignments, the normals of which are, on the one part, the circles of the Rhine and Bassorah, and on the other, the circles of Tanganjika and the lower Loire, are traced on this chart to the 2 000 000th, which is due to Brochant de Villier, Dufrénoy and Élie de Beaumont, and which includes the chart of France on the 500 000th, and the circles of the pentagonal « réseau » added by Élie de Beaumont.

k. *Notes on the geological alignments* by M. B. de Chancourtois (extracted from the *Reports of the Congress of the French Association for the Advancement of Science*, 1878, and from the *Reports of the Geological Congress*, 1878.

These notes afford explanations relative to the three preceding studies (h, i, j).

LOCAL STUDIES.

l. *Distribution of the mineral beds subordinated to the sedimentary deposits, by pencils of alignments parallel to the other geological alignments and to the bearings of the mountain systems in the region of the Haute-Marne*, figured on the geological chart of this department on a scale of the 80 000th, executed by M. Duhamel, revised and completed by MM. Élie de Beaumont and B. de Chancourtois, and published at the National Press, 1862, with a rose of the bearings observed.

m. *Stratigraphic studies* joined to the preceding chart. Papers in which M. Élie de Beaumont has treated the observations upon the relations existing between the bearings established, and those of the circles of comparison of his systems of mountains, and M. B. de Chancourtois, after describing the facts of the alignments observed by him, and which form the subject of the preceding remarks, extends this study to the third part, north-east of France, by the aid of the geological chart on the 500 000th.

n. *Rose of bearings observed and reported, recapitulating the graphic study of the bends, faults and fissures marked out by the mineral beds of iron in the north of France, of the same order as the preceding.*

This survey was exhibited in 1878, and was made on a fragment of the detailed Geological Chart of France on the 80 000th, composed of four of the twenty-two sheets executed before 1874, M. Élie de Beaumont being at the time Director of the service, and M. B. de Chancourtois sub-director, viz : Montreuil, Arras and Saint-Omer, by M. Potier, and Boulogne, by M. Douvillé.

o. *Geological alignments of the region of the Pas-de-Calais, noticed in the observations on the geological exploration of the straits made*, by MM. Lavalley, Larousse, Potier and de Lapparent, with reference to the question of the tunnel. (Extracted from the *Report of the Geological Society of France*, 1875.)

Amongst other indications, this note calls attention to the coinci-

dence of the two bends ascertained to exist near the coasts of France and England in the vicinity of Calais and Dover and of two alignments, previously remarked, of the system the normal of which is the circle of Tanganjika. It also shows the possibility, if not the probability, of accidents of fracture having a perpendicular bearing, that is to say on alignments of the system, the normal of which is the circle of the lower Loire.

p. *Survey of the geological alignments in the environs of Vernon.* (Extracted from the *Report of the Geological Society*, 1871.)

The paper of M. B. de Chancourtois and the lithographed plate executed under his superintendence, form part of the Report presented in common with M. Douvillé, of one of the explorations made after the Geological Congress of 1878. The survey has reference to the alignments of the water-courses of the valleys, of the abrupt sides of the terraces which overlook the Seine; of the faults and fissures of the chalk and lastly the dikes of clay and the kaolin arenas. It sets forth the influence of the clefts of the ground on the Artesian system, of which the subterranean sheet of water on the gault has been utilized by the Madeleine boring represented in the plate.

D. IMITATION OF OROGRAPHIC ACCIDENTS OF UPHEAVAL.

a. *Simple method of imitating the mountain ranges on a globe, and the volcanic basins on a plane, according to the theory of upheavals, also the realization of the automatic imitation of chains of mountains*, by M. B. de Chancourtois. (Notes extracted from the *Reports of the Academy of Sciences*, 1878.)

The means of imitation were first suggested by a communication recalling the first automatic imitation of a chain of mountains obtained about the year 1853, but which remained inedited. Specimens of this automatic imitation were afterwards presented.

b. *Automatic imitation of mountain chains on a globe reduced to the* $^{100\ 000\ 000^{th}}$.

Heliographic reproduction (exhibited in the panel) of two specimens, the first, showing the tendency to polygonal forms with simple

regressions on a thin crust; the second, illustrating the tendency to long alignments with overriding on a thicker crust.

c. *Imitation of volcanic basins on a plane.*

Photographic reproduction (exhibited in the panel) of two specimens, the first, imitating the oval hemicycle which surrounds the Peak of Teneriffe to the S. W.; the second, an imitation of the round hemicycle of the Somma which surrounds Vesuvius to the N. E.

The greater part of the documents, charts, designs, photographs, engravings, heliographs, models and instruments, collected under No. XLVII are due to M. B. de Chancourtois, Inspector general of Mines, Professor of Geology at the School of Mines, who has been instrumental in their production, personally, or with the aid of collaborators of different categories: geographical and geological calculation and drawing, geometrical drawing, photography, copper-plate engraving, heliography, construction of models and instruments of precision, copper-plate and lithographic impressions, printing, editing. The divisions in these various works are indicated by letters designating the operations catalogued above, and in the following list giving the names of the collaborators in alphabetical order:

MM. Arnous de Rivière, printing (A a, C d); Bertaux, construction, editing (B d, C d); Bullot, photography (C e); Chapellier, geographical engraving (C d); Constans, geographical drawing; Dujardin, heliography (A c, B g, D c); Dumoulin-Froment, construction of instruments (A c, 11, 19, 20, B c, C g); Delagrave, editing (B f); Dunod, editing (A a); Erhard, lithographic printing (C d); Eudes, copper-plate printing (C d, B c); Gauthiers-Villars, printing,

editing (C g, C m); Gedlinski, geological drawing (C h, C l); Leclère, letter engraving (C d, C f); Lejard, geological drawing (A c, 2, 4, 6, C f, C h, C i, C j, C n); Lemercier, lithographic printing (C q); Lenoir, geometrical drawing (B g); Lorsignol, geographical engraving (C d); Muret, construction of models (B f); Parquet, geographical drawing (A c, 5, C d, C e); Pérot, geometrical engraving (B d, C f); Picard, geographical drawing (C d); Thoulet, geographical calculation (C d); Wagner, geological drawing (A c, 9, 10, B d, B e, C c).

Five collaborators, who have desired to preserve their incognito, are not mentioned in this list, although their assistance was particularly valuable in respect of the articles (A a, 2, C d, C q, D b).

The names of the authors or editors of the documents, utilized or annexed in order to impart system and methodical arrangement to the work in its entirety, were mentioned in the catalogue as soon as it was issued.

XLVIII

NOTICES RELATING TO THE GEOLOGICAL CHART OF FRANCE [1].

The documents sent to the Melbourne International Exhibition by the Service of the Geological Chart of France may be naturally divided into two distinct sections. Some belong to the general Geological Chart undertaken between 1825 and 1840 by MM. Dufrénoy and Élie de Beaumont, engineers of Mines, under the direction of M. Brochant de Villiers, Inspector general in the same corps; others appertain to the detailed Geological Chart ordained by a decree of the 1st October 1868 and which is in course of execution. Hence the legitimate division of the notices concerning these two series of documents.

GENERAL GEOLOGICAL CHART.

NOTICE.

The general Geological Chart of France is on a scale of $\frac{1}{500000}$, and was engraved *ad hoc* by the authors upon the system of the Hydrographic Chart prepared by the engineers « des Ponts et Chaussées ». It is divided into six sheets, which, united, form a chart of about two metres square.

[1] In this Notice, as in the one entitled « Experimental Geology », the geological terms employed, are taken from Sir Charles Lyell's « Principles of Geology ». The differences between the French and English systems of classification and nomenclature have been carefully observed in order to avoid confusion. (*Translator.*)

The object of the general chart is to depict the most im-tant features of the geological constitution of France, by omplete system of triangulation, in which the rocks are resented by their principal subdivisions.

The explanation contained in the margin of N° 5 sheet, es the detailed list of those which have been adopted. Nothing can more conspicuously display the intelligence ught to bear upon the execution of this vast and remar-le work, than the description itself, it is therefore con-ered pertinent to reproduce it, in extenso.

osits posterior to the ast dislocations of the urface		Alluvions and peats.	
		Alpine and höss diluvium or boulder formation.	
iary	Upper. (Pliocene.)	Old alluvions of the Bresse, sands of the Landes, upper marine sands of Montpellier.	
	Middle. (Miocene.)	Faluns.	Terms employed for the Paris basin.
		Millstone-grit.	
		Fontainebleau sandstone.	
	Lower. (Eocene.)	Gypsum.	
		Coarse limestone.	
		Plastic clay.	
ıer Cretaceous		White chalk and chalk marl.	
'er Cretaceous		Upper (tufaceous chalk) and lower greensand; Wealden or Neocomian formation.	
ıssic		Upper Oolite.	
		Middle Oolite.	
		Lower Oolite (including argillaceous marls of the upper Lias).	
		Gryphite limestone.	
		Infraliassic sandstone.	
		Modified Jurassic formation.	

Triassic	Saliferous and gypseous shales and sandstone (*marnes irisées*) (red marls, Keuper).
	Muschelkalk or conchiferous limestone.
	Variously coloured sandstone (*grès bigarré*) (New Red Sandstone in the English classifications).
Sandstone of the Vosges.	
Zechstein	Magnesian limestone or Permian of the English.
Red sandstone	Rothe todteliegende of the Germans.
Carboniferous	Coal measures.
	Carboniferous limestone.
Transitional	Upper. (Devonian Old Red Sandstone of the English.)
	Middle. (Diluvian or boulder formation.)
	Lower. (Cambrian).
	Modified.
Crystalline (commonly called primitive)	Mica-schist and talcose schist.
	Mica-schist and gneiss.
	Gneiss.
	Granite.
Plutonic rocks intercalated in various formations	Red quartziferous porphyry.
	Diorite and traps.
	Serpentine and euphotide or gabbro.
	Melaphyre and ophites of the Pyrenees.
Volcanic rocks	Trachytes.
	Phonolites or clinkstones.
	Basalts.
	Volcanoes with craters and lava-streams.

The general Geological Chart was published in 1840. Independently of the representation of the formations and their principal subdivisions, by means of different shades of colour, it contains information respecting the beds of mine-

ral substances and the localities where they are worked. The perimeters of grants or concessions are marked out, and smelting works are indicated by conventional signs.

The authors of the general Geological Chart have perfectly comprehended that their work must be followed by an explanatory text as an indispensable complement, and have therefore given it a place in relation to its importance. At the end of the introduction, they explain the order they believed it incumbent upon them to adopt in a description of the strata which compose the mineral system of France. In the first place, they examine the older rocks which constitute the framework, and on which the sedimentary deposits have modelled themselves. They are : the central plateau, the peninsula of Bretagne, the mass of the Ardennes, the Vosges and the littoral mountains of the department of Var.

The sedimentary deposits are then described in the order of their superposition or succession, commencing from the Coal measures and including the Cretaceous formation. The Tertiary rocks and the chains of mountains form the complement of the description.

In proportion to their position more or less detached, or to their actual condition more or less contorted, they constitute appendices which are placed at the end of the work.

In short, the geological description of France, as the authors of the general Chart had originally designed it, was to comprise twenty-four chapters, of which it will suffice to give the titles, in order that the plan of the entire work may be fully appreciated.

Chapter I. — Object of the Geological Chart and the explanation accompanying it. Various public works previously undertaken with the

same object. General features of the formation of France; relation between these features and the interior structure. Precis of the present state of geological knowledge. Summary description of the rocks. Manner of colouring the Geological Chart. Division of this work, founded on the structure of the formations and the general principles of geology. (This chapter was written by MM. Dufrénoy and Élie de Beaumont, jointly.)

Chapter II. — Central formation of France, by M. Dufrénoy.

Chapitre III. — Peninsula of Bretagne, by M. Dufrénoy.

Chapter IV. — The Ardennes, by M. Élie de Beaumont.

Chapter V. — The Vosges, by M. Élie de Beaumont.

Chapter VI. — Littoral mountains of the department of the Var, by M. Élie de Beaumont.

Chapter VII. — Coal measures; description of the different basins, by MM. Dufrénoy and Élie de Beaumont.

Chapter VIII. — Variously coloured sandstone, Muschelkalk and saliferous and gypseous shales and sandstone (marnes irisées), by MM. Dufrénoy and Élie de Beaumont.

Chapter IX. — Jurassic formation (excepting the Jura, the Pyrenees and the Alps), by MM. Dufrénoy and Élie de Beaumont.

Chapter X. — Cretaceous formation in the basin of the N. of France, by M. Élie de Beaumont.

Chapter XI. — Lower Tertiary formation in the basin of the N. of France, by M. Élie de Beaumont.

Chapter XII. — Cretaceous formation in the basin of the S. W. of France (the Pyrenees excepted), by M. Dufrénoy.

Chapter XIII. — Lower Tertiary formation in the basin of the S. W. of France, by M. Dufrénoy.

Chapter XIV. — Middle Tertiary formation (plateaux of the N. W. of France, plain of Gascony), by MM. Dufrénoy and Élie de Beaumont.

Chapter XV. — Upper Tertiary formation (Flanders, Bresse, Landes and the Eastern Pyrenees), by MM. Dufrénoy and Élie de Beaumont.

Chapter XVI. — Pyrenees, by M. Dufrénoy.

Chapter xvii. — Plain of the Rhine, by M. Élie de Beaumont.

Chapter xviii. — Hills of the Haute-Saône, by M. Élie de Beaumont.

Chapter xix. — Jura, by M. Élie de Beaumont.

Chapter xx. — French Alps, by M. Élie de Beaumont.

Chapter xxi. — Extinct volcanoes of central France, by M. Dufrénoy.

Chapter xxii. — Alpine diluvium, alluvions, peats, etc., by MM. Dufrénoy and Élie de Beaumont.

Chapter xxiii. — Correlative distribution of mineral deposits and metallurgical works, by MM. Dufrénoy and Élie de Beaumont.

Chapter xxiv. — General statistics of the working and production of mines in France.

This programme is partly executed. In 1841, the first volume of the explanation of the Geological Chart of France was published (1 vol. large 4to. of 325 pages).

It contains chapters I to VII inclusive. To facilitate the perusal of the text it is accompanied by a plan of $\frac{1}{500000}$th of the six sheets of the Chart, which reproduces the representation as far as possible.

Volume II was published in 1848, and entirely devoted to the description of the Trias and Jurassic formations, comprised in chapters VIII and IX (1 vol. of 813 pages).

The plan, adopted first for the publication of the text, has been modified by the addition of a complement of which the preface of volume II (1848) announced the appearance in these terms: « We think it right to announce to our readers that the Administration of Mines, with the view of furnishing engineers and geologists with an easy method of studying conchology, which forms one of the essential elements of practical geology, has authorized us to devote a

volume to the description of the shells most characteristic of the formations; the fossils will be depicted either from specimens collected by ourselves, or from others more complete belonging to the collections of the School, the original bed being properly verified. The description of these fossils will be composed by M. Bayle, who has for three years delivered lectures on paleontology at the National School of Mines, and the volume will form the complement of the explanation of the Geological Chart of France. »

The atlas of vol. IV of the explanation of the Geological Chart appeared in 1878, and contains 158 plates, showing the principal fossils of the formations and 18 plates, of the flora of the coal period. The plates of fossils were executed under the direction of M. Bayle, engineer in chief of Mines, and present several new species. The plates of the coal vegetation are due to the assistance of M. Zeiller, engineer of the Mines. An explanatory note is attached to each of the plates, and a descriptive text accompanies the second part of the atlas.

The Geological Department has sent to the Melbourne Exhibition, all that has yet appeared of the text explanatory of the general Chart.

DETAILED GEOLOGICAL CHART OF FRANCE.

GENERAL REMARKS.

A decree of the 1st October 1868 ordained the execution of the detailed Geological Chart of France at the expense of the State. A ministerial order of the 15th of the same month

organized the special service charged with the accomplishment of this great work, and placed it under the principal direction of M. Élie de Beaumont, Senator, Member of the Academy of Sciences, and Professor of Geology at the School of Mines.

The official report of the 30th September, stated the reasons actuating the decree, and at the same time definitively established the object of the work and the general conditions of its execution. The object specified was to resume the work inaugurated in 1835 by the institution of departmental geological charts, and to complete it by the addition of views of the whole, by which means alone the homogeneity of the undertaking could be secured.

The essential bases of the execution of the work were also defined in the report. The geological bearings of the ground were to be ascertained and set down on the Chart of the War Office on a scale of $\frac{1}{80000}$th. A term of ten years was considered sufficient for the accomplishment of the surveys of the two hundred and ninety-six sheets of this chart into which the French territory was at that time divided. Two hundred copies of each sheet were to be issued, and finally, the cost of the work was estimated at 1 million francs.

At the death of M. Élie de Beaumont, which took place in 1874, the service of the detailed Geological Chart was completely reorganized. The Administration of Public Works exercised great caution in proceeding with it, and took no further steps until after the report of a commission appointed to examine the subject. The principal result of the inquiry was to establish the manifest disproportion between

the plan proposed for the execution of the work, and the means at the disposal of the Geological department for bringing it to a satisfactory conclusion. The remedy for this state of things appeared to the Commission to be found in the aid of assistants employed in the localities to be explored, and that they should be taken from the corps of Mines as well as from persons unconnected with it.

On the other hand, the attention of the Ministry of Public Works was directed to the necessity of giving to the Geological Chart a character that should constitute it a work by itself, superior to all others, and capable of being freely received as an authority admitting of no discussion on the part of the public for whom it was intended.

The ministerial order of the 21st January 1875, while reconstituting the Geological Service, disposed of these difficulties in the most felicitous manner. To assist the Director, who was responsible only to the Minister, a commission was appointed to advise upon questions concerning the execution of the Chart.

During the last five years, all the efforts of the new Direction have been devoted to putting in practice the ideas which had influenced the reorganization of the Service. Notwithstanding that the comprehensive reform, instituted in the recruitment of the personnel, could not become effective before 1876, on account of the insufficiency of the sums voted, and consequently that only four years have elapsed, it has already been productive of excellent results. From the first year, the Geological Service which had previously been reduced to six active members, was augmented by thirteen assistants, selected from scientific professors and

mining engineers; it now numbers thirty-seven members. With the present staff and an endowment of 80 000 francs, the Service is in a position to communicate an impulse to the publication of the Geological Chart, and to finish it in a period of eighteen years, reckoning from 1876, ; a rate of progresss that corresponds to an average production of fourteen sheets a year.

Amongst other reforms instituted in the execution of the Geological Chart, that which has been effected in the mode of publication, is too important to be omitted. In accordance with the advice of the consulting Commission, the issue of the sheets of the Chart has been increased from two hundred to five hundred copies, and printing in colours has been substituted for colouring by hand. This modification has permitted a reduction of one half in the price of each copy.

The price has been reduced, and it now hardly exceeds that of the engraved copies of the Chart of the War Office, and in certain cases is even lower.

The Service of the detailed Geological Chart has sent to the Melbourne International Exhibition;

1. Large atlas, containing all the documents published up to this date;

2. The French Alps, comprising the sheets on the $\frac{1}{80000}$th (Grenoble, Vizille, Briançon and Saint-Jean-de-Maurienne);

3. Panel containing a geological survey of the Alpes-Maritimes to the East of the Var and the Vésubie, also the sheet of Antibes on the $\frac{1}{80000}$th;

4. Geological survey of the environs of Givet (Ardennes) on the $\frac{1}{40000}$th;

5. The volcanic formation of Cantal, in the same scale;

6. Geological survey of Mont-Dore on the $\frac{1}{10000}^{th}$;

7. Part of the geological bearings of the Tertiary basin of the S. W. comprising the sheets of Bordeaux, the Teste de Buch, Sore et Mont-de-Marsan, with a longitudinal section of the basin;

8. A work entitled, *Micrographic Mineralogy;*

9. Geological description of the district of Bray.

ATLAS.

The atlas contains all the documents of the detailed Geological Chart now offered for sale.

They are as follows :

1. Thirty-six sheets of the Chart of the War Office with the geological bearings, viz:

N° 1, Calais; N° 2, Dunkerque; N° 3, Boulogne; N° 4 Saint-Omer; N° 5, Lille; N° 6, Montreuil; N° 7, Arras; N° 8, Douai; N° 9, Maubeuge; N° 10, Saint-Valéry; N° 11, Abbeville; N° 12, Amiens; N° 13, Cambrai; N° 18, le Havre; N° 19, Yvetot; N° 20, Neufchâtel; N° 21, Montdidier; N° 22, Ham; N° 31, Rouen; N° 32, Beauvais; N° 33, Soissons; N° 47, Évreux; N° 48, Paris; N° 49, Meaux; N° 64, Chartres; N° 65, Melun; N° 66, Provins; N° 69, Nancy; N° 78, Nogent-le-Rotrou; N° 79, Châteaudun; N° 80, Fontainebleau; N° 81, Sens; N° 93, le Mans; N° 95, Orléans; N° 109, Gien; N° 122, Bourges;

2° Six plates of longitudinal sections relating to the sheets of Paris, Meaux, Beauvais, Rouen, Évreux and Neufchâtel.

3° Four plates of vertical sections, annexes of the sheets of Paris, Meaux and Beauvais;

4° Four plates of photographic perspectives;

5° Four plates of fossils belonging to the Parisian Eocene formation;

6° Lastly, ten tables of generalities (title, preface, technical description catalogue with explanatory note, general geological descriptive catalogue, system and mode of application).

With the exception of the sheet of Nancy, the sheets of the Geological Chart published up to this date, form a compact group, which embraces Flanders, Artois, Picardy, the Isle of France, Brie, Bauce, Gatinais, Upper Normandy and Perche. Some parts of Maine, Lower Normandy, Sologne and Berri will also be found in this group.

The whole work contains about the sixth part of France and the entire Tertiary basin of Paris, and is sufficiently large to show a part of the Jurassic and Cretaceous cincture surrounding Paris, and the French part of the Anglo-Flemish Tertiary basin. The extremities of the Paleozoic rocks of Ardenne and the Norman Bocage appear on two sheets; Maubeuge and Nogent, towards the N. W. and S. W.

The greater part of the sheets were shown at the Universal Exhibition of 1867. At that period, Élie de Beaumont had endeavoured to obtain a sufficiently detailed geologi- chart of the Paris basin by uniting departmental charts, and to fill up the hiatus caused by the absence of certain of these, and to unify those already, in existence, he had recourse to his personal notes, and to those placed at his disposal by the engineers, only eighteen months before the Exhibition. This attempt resulted in the production of a chart of the country, in which the great features of the ge-

ology of the North of France were delineated, but the work was wanting in the precision which characterized the topographic chart on a larger scale, and in which sufficient attention was not paid to the knowledge acquired since the preparation of the departmental charts which had served for its base. A complement of explorations and a complete revision were therefore necessary, and the panel now exhibited is the result of the revision. If all the subjects for inquiry presented by an examination of the Paris basin have not been satisfactorily explained, especially those concerning the most recent deposits, a comparison of the old chart with the new, will nevertheless display an appreciable advance in the science of geology.

In the very numerous series of subdivisions of the Tertiary formation, two new terms have been introduced; granitic sands, posterior to the most recent lacustrine deposit of the Paris basin, and the marls of the Orléanais, hitherto confounded with the limestone of Beauce, of which they constitute the upper part. By the introduction of this new term, the Parisian series approaches that of the S. W., and on the one part, the general tendency of the strata of the Parisian basin to encroach more and more on the South, and on the other the independence of the lacustrine limestone in relation to the sands of the Sologne, are emphasized by the distinct colouring imparted to this limestone on the chart.

The prolongation in an easterly direction of the strata that had been recognized in the environs of Paris, has been followed step by step, and it is known that several of them disappear before they attain the great cliff which bounds the Tertiary basin on the Champagne side; an exact

knowledge of the limits of each is therefore indispensable for the purpose of determining the importance, the direction, and the epoch of the various oscillations that have, at different periods, caused the emergence of the Parisian basin from the lacustrine or marine waters, or its disappearance beneath them. With this view, the deep valleys that break the plateaux of the Brie, to the South as well as to the North of the Marne, have been carefully examined. Strips of the Fontainebleau sands, hitherto unobserved, have been indicated on this plateau, and it is interesting to observe, that on this side, the sands have noticeably passed beyond the millstone-grit of the Brie, so that they come into contact with the green marls and the gypseous formation.

In leaving Paris, the thickness and number of terms of the Tertiary series diminish rapidly towards the North, and the underground formation consists absolutely of chalk, covered here and there by some Eocene fragments, interesting to study, since they supply the only positive terms of comparison between the Parisian and Belgian basins; the singular disposition of these narrow strips at the bottom of the chalk pockets, their perturbed and inclined stratification, contrasting with that of the subjacent chalk, have also been pointed out.

The old charts did not afford facilities for a detailed survey of geological movements, in the vast region comprising Normandy, Picardy and Artois.

A study of this character requires that the divisions represented by distinct shades of colour, should not be sufficiently thick to conceal the important disturbances of level by one uniform colour. The subdivisions introduced into

the upper white chalk: chalk containing belemnitella mucronata, chalk with micraster, and chalk marl, which had previously been figured on the chart by a unique tint, have permitted the representation of the numerous inflections of the chalk throughout this part of the Parisian basin.

These inflections are subordinated to two principal directions, one of which, by far the most important, is also that of the two great lines of faults: the axis of Bray and that of Artois; the lines of these faults and of those of the Seine, have been studied with great care, and to complete the graphic representation of the underground formation, lines of level have been formed in Artois and Flanders, showing, according to information furnished by the survey of the surface, and by a great number of borings, the undulated surface formed by a determinate stratum of chalk, or more exactly, the surface of separation from the gault and from the Rouen chalk.

The geological bearings of the formation in thirty six sheets of the atlas have been executed by MM. Fuchs, Potier, de Lapparent, Douvillé and Clérault, engineers of the Mines; by M. Gosselet, Professor of Geology to the Faculty of Sciences at Lille, and by M. Guillier, « conducteur des Ponts et Chaussées », at le Mans. The line of the outcrops of chalk under the Pas-de-Calais has been designed according to the surveys executed in 1875 and 1876 for the French Company of the submarine tunnel between France and England, by MM. A. Lavallée, engineer, delegate of the Company, Larousse, hydrographic engineer of the navy; Potier and de Lapparent, engineers of the Mines.

The plates of the longitudinal and vertical sections were executed by the engineers of the central service.

Part of the general remarks appeared in 1874, under the signature and responsibility of M. DE CHANCOURTOIS, at that time engineer in chief of Mines.

FRENCH ALPS.

SHEETS OF GRENOBLE, VIZILLE, SAINT-JEAN-DE-MAURIENNE AND BRIANÇON.

The four sheets of Grenoble, Vizille, Saint-Jean-de-Maurienne and Briançon, comprise a specimen of the geological constitution of the French Alps, almost complete in its details. The surface represented by these four sheets is divided into three regions : 1. the plains and plateaux of lower Dauphiné; 2. the Subalpine chains; 3. the Alpine chains.

1. The region of the *plains and plateaux of lower Dauphiné*, of which about one fourth is comprised in the N.W. part of the Grenoble sheet, is very uniform in its constitution; it is composed chiefly of the upper and middle beds of the *marine molasse*, in a state of soft sandstone with calcareous cement or pudding-stone with perfectly rounded pebbles; the strata have long undulations, with inclinations generally imperceptible. In the upper part of this group, a freshwater deposit is intercalated, that of the *argiles à lignites* of the Tour-du-Pin, and forms a stratigraphic horizon with strong characteristic points; then come sands and pudding-stones identical with those beneath, and alternating with the fresh-

water marls. These alternations of varying deposits, succeeding the marine molasse, correspond to a period of progressive elevation and to a regime of lagoons and littoral pools, which was followed by a general emersion. The marine deposits of *Pliocene* fossils do not appear to have penetrated the limits of the Grenoble sheet, although at the present time they are recognized in some points not far from the Western side. This region of lower Dauphiné is also remarkable for the great development of the *old alluvions* (valley of the Côte-Saint-André and Saint-Marcellin) and the *glacial deposits*, which cover all the lower region of the department of the Isère, excepting the plateaux of Bonnevaux and Chambaran, situated North and South of the great valley of the Côte-Saint-André.

2. The region of *Subalpine chains* includes, in the Grenoble and Vizille sheets, the calcareous formations of the Chartreuse, Lans, the Royans, the Vercors, etc., bounded on the East by the course of the Isère and that of the Drac, above their confluence at Grenoble.

These masses are chiefly formed by a great development of the lower beds of the *Cretaceous formation*, viz.: the *Urgonian* stratum, represented by a vast mass of compact limestone, which comprises all the more salient orographic features; — the *Neocomian* (also called *Valanginian*); — and a lower stratum, equally important, which may be denominated *Infra-Neocomian*, including the marls with *Belemnites latus*, and the cement strata of the Porte-de-France of Grenoble, which correspond to those of Berrias (Ardèche). These three strata present a general thickness of from 1 000 to 1 200 metres. The remainder of the Cretaceous series

is less completely developed : the *marnes aptiennes* only appear in some points of the extreme South of the Vizille sheet, but become of greater importance a little more South in the Die sheet, where they seem to replace the *Urgonian* limestone. The *gault* forms a stratum of great regularity, but always very thin. The middle and lower beds of *chalk* are irregularly developed and sometimes wanting, so that the *White Chalk*, represented by sandy limestone (*lauzes*) and limestone with kidney shaped silex, rests directly on the gault.

Below the Cretaceous series, thus constituted, the *Jurassic formation* offers some peculiar characters.

In the most westerly of the small chains of the Chartreuse, which are in reality the continuation of the last chains of the Jura, some indications of the upper Jurassic strata are seen to crop out, as in the Jura, and the last trace is represented by the *coralline* outcrop of the Échaillon, at the angle of the Isère, 16 kilometres N. W. of Grenoble. But everywhere else in the true Alpine chains, the highest stratum, recognized to be incontestably *Jurassic*, consists of a vast mass of compact limestone of a dark brown, with spathic filaments, frequently designated as limestone of the Porte-de-France and Grenoble, of which the constancy of character is fully recognized throughout the Alps and in the Mediterranean districts. In respect to their fossils, these limestones correspond to the zone containing *Ammonites tenuilobatus* of the Eastern and Southern Jura, and these facts considered collectively tend more and more to the conclusion that they form a synchronic equivalent of part of the *coralline* stage, to which they had been previously attributed.

Between these limestones and the lower Cretaceous strata, — the Berrias or the Porte-de-France cement layers, — a zone of limestones is also found, the petrographic character of which would not enable them to be distinguished from the lower mass, but they contain a system of fossils proper to them (*Terebratula janitor*, *Ammonites ptychoïcus*, *A. Liebigi*, etc.). Their classification has been the subject of much discussion, and does not appear to adapt itself to any of the divisions admitted into the series of formations of the Jura or the North of France. All that can be affirmed with any degree of certainty, is that, with the *Infra-Neocomian* which covers them, they ought to find a place in some part of the immense interval that exists in the Jura, between the *coralline* bed and the *Valanginian* stratum, which is the base of the *Neocomian* properly so called.

Beneath the escarpments formed by the Jurassic limestone of the Porte-de-France, we find argillaceous limestone, strongly characterized *Oxfordian* marls, and a layer of black schists representing the lower *Kelloway* rock. The lower beds can rarely be observed in this region of Subalpine chains: in the Grenoble and Vizille sheets, the *Bath Oolite* is only represented on the eastern boundary of the region, by black limestone of doubtful character and containing few fossils.

The valley of the Isère, of Grenoble at Moirans, intersects the region of Subalpine chains in a transversal direction. On the right bank, the mass of the Chartreuse owes its relief principally to the great *faults*, all bearing to the east, and forming the same number of steps, more and more elevated, from West to East: between these faults, which are in close proximity, the flexures have only partially operated and are

always of an irregular character. On the left bank, the masses of Lans, the Royans and the Vercors, show the continuation of a part of the same faults, but less numerous and more distant, between which the regular arches and valleys of flexure are largely developed, in orographic forms analogous to those of the chains of the high Jura.

Strips of *Marine molasse*, participating in all the dislocations of the Cretaceous formations, are found in the foldings of these various masses, up to an altitude of 1 500 metres, and demonstrate that the faults and flexures, which shaped these Subalpine chains, date from the epoch of the deposit of the Molasse.

3. *Region of the Alpine chains.* — The parts of the Grenoble and Vizille sheets, situated on the left bank of the Isère, and the right bank of the Drac, belong to the region of Alpine chains, equally with the whole extent of the sheets of Saint-Jean-de-Maurienne and Briançon.

This region is distinguished from the preceding by the entire absence of the *Molasse* and the *Cretaceous* formations, and in the limits of our four sheets, the *Jurassic* is only represented by strata lower than those enumerated in the region of the Subalpine chains. The existence of the *Bajocian* stage is only attested by a very small number of fossiliferous deposits, while the *Lias* is well developed and the fossils, though rare and frequently in bad preservation, tend to indicate the existence of all the different layers of this group. The *Trias*, rudimentary on the Western border, becomes very prominent here, and possesses special characteristics. The *coal grit* is represented by the important layer of *anthracite grit*. In addition to which the *Azoic Crystalline rocks*

are found in considerable masses, which include the most continuous and most salient features of relief.

This region may be divided longitudinally into four zones, unequal in breadth and importance, and delimited by the great lines of fracture or *faults*, with which the distribution and variations of the different formations are in close relation.

First Alpine zone. — This zone is the most important in the French Alps, and comprises the various Crystalline rocks of this side: the chain of Belledonne or the Western Alps, extending from Valbonnais (Vizille sheet) to Beaufort (Albertville sheet), following the direction N. 26° E.; — the chain of the Grandes-Rousses, in Oisans, in the prolongation of which appears the small mass of Rocheray, near Saint-Jean-de-Maurienne; — and lastly the great mass of the Pelvoux (Briançon sheet). To this Alpine zone, but farther North, belong Mont Blanc and the Aiguilles Rouges, the Bernese Alps and the Saint-Gothard; and to the South the great Maritime Alps.

The general character of all these masses consists in their being formed of *Crystalline schists*, *gneiss* and granitoid rocks, always in a contrary position to the strata, parallel to the stratification of the gneiss, with which they alternate regularly, and are connected by imperceptible transitions. The granitoid rocks in veins are rare and of small extent. The stratification of these ancient rocks of the first Alpine zone is always considerably inclined, and they may be considered as forming, in their entirety, two great folds in the form of an A, broken at their summits and occupying a breadth of about 25 kilometres each. The chain of Belledonne represents the *West* point of the first fold, to the *East* slope of

which should belong the Grandes-Rousses, the Rocheray and probably Mont Blanc. The second fold would be visible only in the mass of the Pelvoux.

In the axis of each of these masses, and resembling the fundamental rocks, are seen to crop out *granitoid gneiss*, with white orthoclastic felspar and shining black mica, passing to foliated gneiss, then to *mica-schists*, with beds of *saccharoid limestone*, while the exterior slopes are formed by a great system of *chloritic talc-schists*, which, as subordinate rocks, more or less developed, inclose *schists* and *hornblendic gneiss* and *granitoid protogines*, alternating with *chloritic gneiss*. The protogines of the Pelvoux, as well as those of Mont Blanc, are thus outside the axis of the formation, and, as affirmed by Cordier, are only large stratiform layers, intercalated in the great system of talcose schists.

The *anthracite grits*, representing the *Coal measures*, are sometimes appreciably at variance with the Crystalline schists, but their strata most frequently assume exactly the inclination of these schists and the dislocations that have placed them in their vertical or inclined position. Bands of the *anthracite grit* are found thus compressed in the folds of the *Crystalline schists*, apparently alternating with them. Thus the dislocations that have raised the Crystalline schists of the formations of the first Alpine zone are generally posterior to the *Coal measures*.

On the other hand, the Secondary rocks frequently appear in horizontal strata, placed on thin layers of *coal grit* or *Crystalline schists*. The *Trias* is rudimentary and often wanting, as for instance in the great part of the Oisans; where it exists, it comprises *hard sandstones, white* or *variously coloured*

(called *quartzites*), *dolomites*, and accumulations of *anhydrite* and *gypsum*. The *Lias* is very thick, and principally in the form of argillo-calcareous schists, frequently merging into true slate.

The deposits of *Trias* and *Lias* are in horizontal strata, on the layers of *Crystalline schist* and of *coal grit*, already uplifted nearly as we see them at the present time. The ulterior movements consisted in a general rising and dislocation of the ancient surface by *faults*, following which, the strata of the *Lias* and *Trias*, being flexible, have subsided and adapted themselves, by flexure, to the new forms of their dislocated base, in such a manner that it is only on a few summits and terraced plateaux, that these Secondary rocks are found in horizontal strata, while on the flanks of the valleys, they are always extremely inflected and disturbed.

Second Alpine zone. — A *fault*, perfectly continuous for a distance of 150 kilometres, passing by Saint-Jean-de-Maurienne and the necks of the Madeleine in the North, and the Lautaret in the South, shows the *Lias* of the first zone, meeting an outcrop of *Trias* which belongs to our second zone. This latter, which has only a moderate breadth of 5 to 12 kilometres, is formed chiefly of *Trias* and *Lias* much contorted, under which appear occasional strips of *coal grit* or *Crystalline schist*. Towards the Northern limit of the sheet of Saint-Jean-de-Maurienne, in the environs of Moutiers, we begin to perceive in the upper layer of the *trias*, the type of *glossy grey schists*, which is developed to an enormous extent in the continuation of this zone through the Tarentaise, the valley of Aosta, and the Valais. The *Lias* has a tendency to merge into compact limestone, more or less magnesian; the

transition manifests itself very distinctly in the mass of the Encombres between Saint-Jean and Saint-Michel, and the transformation becomes complete in its extension to the South, by Valloires and the neck of Galibier. In short, it is to the second zone, that the termination of the *nummulitic* formation belongs, a formation which extends from the Mediterranean coast to the S. E. side of the mass of the Pelvoux, and continues in a narrow band, to its termination between Saint-Jean-de-Maurienne and Moutiers, to the peak of the Cheval-Noir.

These different formations of the second Alpine zone, have been much overturned, and are generally folded back and inverted upon themselves at the edge of another great *fault*, which separates them from the third zone, passing by Saint-Martin-de-Belleville, Saint-Michel and the Monestier-de-Briançon.

Third Alpine zone. — This zone is chiefly formed by the *anthracite grit*; it constitutes the great band of sandstone which extends through the Briançonnais, the Maurienne, the Tarentaise, the upper part of the Aosta valley, and after narrowing in the Valais, terminates in the environs of Sion. Its greatest breadth is 18 kilometres, between Saint-Michel and Modane. The *Coal formation* attains here a thickness of more than 2 000 metres; it supports strips of *Trias* and *Lias* more or less extensive, and at some points may be observed to rest on the *Crystalline schists* particularly at Modana. Unlike the facts mentioned in connection with the first Alpine zone, all these formations display a parallel stratification. The same remark may be made with respect to the rare outcrops of the *Coal grit*, or the *Crystalline schists* of the

second zone; and also even in the fourth zone, the Secondary rocks are always found in parallel stratification, resting on the ancient schists.

At Modana and several other points, the *anthracite grits* are clearly bounded, on the East, by a *fault* against which the *Trias* and *Lias* strata of the fourth zone stop abruptly. This latter is therefore weakened in relation to the third zone, as is the second in relation to the West. In the same manner, the zone of *anthracite grit* really represents the key of the arch of the entire French Alpine chain, through which other zones are placed in descending steps, on the Italian as on the French side.

Fourth Alpine zone. — This is the largest of these zones, and has an average breadth of 60 kilometres; the Western boundary passes by Briançon, Modane and Bozel. So far as our present knowledge extends, it does not appear to contain any strongly characterized deposit of *anthracite grit* belonging to the *Coal formation*. The *Crystalline schists* are covered directly, and in a parallel manner, by the enormous development of the *Trias*, with the aspect of *grey glossy schists* that it presents in the second zone, in Tarentaise: the *glossy schists* of Queyras, Bardonnèche, the upper Maurienne, commencing from Modana, etc., containing numerous accumulations of *gypsum* and superposed on *dolomites* and *quartzites*, as those of the *Trias* of the other zones. The *Lias* is represented by a great mass of compact limestones, a continuation of those of the Encombres and the Galibier (*limestone of the Briançonnais*). The formations of Crystalline schists penetrate into the rents of these rocks, in the same manner as in the central arches of the Jura chains: as for instance,

the mass of Mont Viso, certain parts of the mass of the Vanoise, Mont Pourri, etc. The greater part of the Italian side is formed by a large band of *Crystalline schists*, on the Western slope of which the *Trias* rests in parallel stratification, while on the other side, these schists border the plain from Saluces to the lake Majeur.

The geological bearings on the sheets of Grenoble, Saint-Jean-de-Maurienne, Vizille and Briançon, which comprise the Alps of Dauphiné and Savoy, were executed by M. Lory, Professor of Geology, senior member of the Faculty of Sciences at Grenoble, corresponding member of the Academy of Sciences, and connected with the service of the Geological Chart of France.

REGION OF THE MARITIME ALPS.

TO THE EAST OF THE VAR AND THE VÉSUBIE.

The Geological Chart exhibited, comprises that portion of the department of the Maritime Alps, which is situated between the Var and the Vésubie on the West, the Italian frontier on the North and East, and the sea on the South, and is on a scale of $\frac{1}{50\,000}$.

The formations in this portion of the department of the Maritime Alps, belong to the periods

Quaternary or Post-Tertiary,
Tertiary,
Secondary,
Primary,

and to different eruptive and Crystalline rocks.

Quaternary or *Post-Tertiary rocks.* — Besides the recent alluvions, which fill the beds of torrents and form banks the Quaternary rocks contain breccias (*brèches*), more or less compact, which are found at different points in the fissures of the Jurassic rock.

These breccias are usually formed of the debris of rocks in contact, and are cemented by calcareous concretions, or by a ferruginous cement more or less red. On the Western side of Mont Boron, this breccia is composed of well rounded shingles.

In many places, they contain bones and freshwater shells, frequently mingled with marine shells.

As examples of these breccias, may be cited the deeply fissured rocks, found to the West of the port of Nice and the South-West side of Mont Boron.

Tertiary rocks. — In the district with which we are concerned, the formations belonging to the Tertiary period may be divided into two distinct groups, and we have never found them in immediate relation with each other.

Commencing from the upper strata, the first of these groups is composed of:

1. Beds of greyish sandy clay, or fossiliferous yellow sand, intercalated, at certain points, betwen beds of pudding-stone.

2. Beds of pudding-stone or compact sand, alternating with beds of fine sand or more friable gravel, destitute of fossils.

3. Beds of fine sand or bluish clay, containing many fossils.

Some types of these formations may be noticed;

The first are found on the road from Nice to Aspremont,

opposite the chapel of Saint-Pancrace, and on the road from Aspremont to Tourette, in the Western side of Mont Boron;

The second are met with in the valley of the Magnan at Roquebrune;

The third, at the confluence of the Laghet and the Paillon, and in the valleys of the Mantega and the Madeleine near Nice.

The superposition of these strata and the fossils collected in them, lead to the conclusion that they should be classed in the Pliocene, those of the third series being more particularly fit for assimilation to the Subapennine strata.

The second group of Tertiary rocks contains :

1. Beds of sandstone, frequently schistose, alternating with beds of sand more or less coarse, destitute of fossils;

2. Beds of limestone, very argillaceous, of a bluish grey colour, with a cross or false stratification, and destitute of fossils.

3. Beds of iron-grey limestone, siliceous or slightly argillaceous, with numerous fossils.

The series of types of these formations is found along the road from Nice to Turin, between the bridge of the Fuont-de-Jarrier and the Escarène.

We have found no fossils in the strata comprised under N^os^ 1 and 2, and we are therefore precluded from the possibility of assimilating them to the recognized divisions.

Nevertheless, from their position, it appears possible to consider them as constituting part of the Upper Middle Eocene.

With regard to the strata comprised under N° 3, judging from the fossils contained in them, they appear to correspond to the coarse Parisian limestone.

Secondary rocks — The Secondary rocks of the region under consideration, answer to the Cretaceous and Jurassic periods.

In points of general appearance, the Cretaceous strata may be divided as follows:

1. Thick layers of argillaceous limestone, frequently hard, yellow at the surface, of a grey colour more or less dark internally, and separated by layers of clay.

2. Thin layers of kidney-shaped masses of argillaceous limestone, of a dark grey internally, but of a light yellow colour externally, penetrating considerably the thicker argillaceous strata of a dark grey, which alternate with them.

3. Grey schistose strata, frequently glauconian to the point of appearing black, and becoming entirely sandy, resting on beds of very hard limestone, of a yellow or greenish appearance, according to the oxydation of the glauconium with which it is impregnated. Under these calcareous strata, are found beds of limestone slightly argillaceous, and of a dark bluish grey.

In order to make the series of these strata nearly complete, the ascent of the neck of Braus may be cited as an illustration, commencing from Roche-Taillée, near the chapel of Saint-Laurent.

Fossils are found in all these strata, but principally in the lower ones.

According to the fossils we have collected, the upper beds correspond to the white chalk and the chalk marl, the middle more particularly to the Rouen chalk, and the lower to the gault and the Neocomiam.

In the same manner from their physical character the

Jurassic strata may be distributed into the following divisions:

1. Thin beds of hard limestone, light yellow or pinkish grey.

2. Thick beds of limestone, white or light grey, generally dolomitic, and passing into fragmentary and even sandy dolomite, in the vicinity of faults and fractures.

3. Thin beds of light yellow limestone, separated by very thin beds of clay.

These colours, which may be considered as those of the Jurassic strata in the vicinity of the sea-coast, pass into black as they advance towards the North, i. e. towards the summit line of the Maritime Alps.

There are but few fossils in the Jurassic strata, and on this account it is difficult to assimilate them to recognized divisions.

Nevertheless, judging from the fossils collected, it appears that the formations designated under N^os^ 1 and 2, may be ranged in the Coralline and the others in the Oxfordia .

The types of these strata may be remarked on the road from Nice to Turin, at the foot of the neck of Braus at the Roche-Taillée.

Primary rocks. — As in the preceding description, according to the appearance of the strata, the Permian may be divided as follows:

1. Strata of hard sandstone, varying in colour between white, grey, green and pink.

2. Smooth schist, claret colour with greenish veins.

3. Large grained, coarse red sandstone.

We have never found fossils in these formations; but

from the investigations of M. Potier, engineer of Mines, on the slopes of the Esterel, these strata should be classed in the Permian.

One of the best localities for the examination of these formations, is the road from Nice to Turin, between Fontan and the frontier.

Eruptive rocks and Crystalline formations. — The eruptive and Crystalline rocks appear, in the region now under consideration : the first as trachytes at the point of Aggio and its vicinity; the second as gneiss and mica-schists, crossed by veins of granite above Berthemont and Saint-Martin-de-Lantosque.

Mineral matters. — Among the mineral substances more or less suitable for working, we shall confine ourselves to remarking some lignites (probably Cretaceous) in the neck of Villefranche, at Mont Agel, etc.; some lodes of native and carbonated copper, in the Permian above Roquebilière, of orpiment, in the Cretaceous near Luceran, and lastly of gypsum, on the subject of which we think necessary to give some details, considering the importance of the deposits.

It is most difficult to determine the position of these deposits, in relation to the surrounding rocks, since they are invariably situated on lines of dislocation of the formations, and are covered by conglomerates.

Nevertheless, this circumstance connected with the fact of the existence, in the middle of the gypsum, of fragments of neighbouring rocks presenting all degrees of transition from the pure rock to the gypsum, has led us to conclude, that these gypsums had been formed on the spot, to the detriment of the dislocated rocks, and, whatever may be their

period, by eruptions of mineral waters and probably of gas, which forced their way following these lines of fracture.

This view of the subject explains the fact that, on the Cimies road for instance, the Jurassic rock appears to be the base of the gypsum, while on the other hand in the road from Sospel to Menton, below the chapel of Saint-Pancrace, the gypsum is formed at the expense of the Cretaceous rock.

This phenomenon of the transformation of limestone rocks nto gypsum, following the direction of the dislocations, also explains the fact that, in the vicinity of faults and fractures, the Jurassic rocks have generally an excess of dolomite, to the extent of causing a complete disappearence of the limestone, so that the rock is frequently found in a sandy state.

Lines of summit, of watercourse and of upheaval. — The portion of the department of the Maritime Alps with which we are now occupied, presents numerous lines of dislocation and very distinct faults.

By way of illustration, we subjoin the following instances which we have observed.

In the first place, we shall point out the faults constituting three principal steps, dipping to the North, which extend from the rock of the castle of Nice to Cape Martin.

By joining to these faults those which determine the valley of Saint-André, and that of the Vésubie as far as Saint-Jean-de-la-Rivière, then that of the Paillon between Peille and the Escarène, we shall constitute a vast promontory, the borders of which are formed by the perpendicular Jurassic rocks, which the Cretaceous, and then the nummulitic formation surmount in almost regular superposition.

The same phenomenon reproduces itself on a smaller scale, around the neck of Braus.

The contours of these faults do not appear at the first view, to obey definite laws, and this by reason of the number and varieties of the directions they take; nevertheless, a closer inspection will enable us to recognize that certain directions are followed with extraordinary persistence, and that these directions have an unmistakable relation to the various lines of water-course and summit.

Thus for example :

1° If we draw a line from Cape Aggio, where the trachyte crops out, to the point of the Corne-de-Bouc (2 460 metres), on the Northern frontier, this line passes by the Tête-de-Chien, (250 metres), by Mont Agel (1 148 metres), by Mont Baudone (1 263 metres), by the valley from Castillon Sospel, by the crest which extends from the Beolet (1 133 metres) to the summit of the Gonella (1 844 metres) and terminates at the summit of the Abisso, on the great chain;

2° If we draw a parallel to the first of these lines, by the chateau of Villeneuve-Loubet, where the trachyte also crops out, we shall see it pass through points not less remarkable, viz:

The perpendicular peak of the Gaude, behind Saint-Jeannet (834 metres); the Cime (833 metres), near Bonson; the embouchure of the Tinee, the counterfort which extends from the Tour to the neck of Monei (1 470 metres), Mont Cianorias (1 998 metres), the Balme of the Frema (2 252 metres), and finally the summits of Frema-Morta, on the grand chain;

3° We shall also see that the summit line of the prin-

cipal chain of the Maritime Alps, between the two lines we have just noticed, follows a perpendicular in their direction, and that it is the same for the valley of the Var, in its course from West to East;

4° That these two directions are found, as may be seen on the chart, in the faults situated along the road from Corniche, and along the mass of Mont Agel, etc.

To this first group of directions we may add another, clearly indicated : 1° by the line which follows the Bevera from the frontier to Sospel, and borders the perpendicular sides of the plateau extending behind Grasse and Saint-Jeannet; 2° by the line which, commencing from Mont Panaglia, passes through the valley of Saint-André and a part of that of the Tinée.

The geological outlines and bearings were executed by M. Cambré, engineer « des Ponts et Chaussées ». The collection of specimens and fossils, to the number of two thousand, was presented to the School of Mines.

ANTIBES SHEET.

The Antibes sheet includes all the mountainous region known under the name of the Estérel; the Crystalline formation of the Maures loses itself in the sea to the S.W., while the high calcareous plateaux of the N.W. unite with the Alps; in the East, the most recent Tertiary formations present themselves with the characteristics they possess in the county of Nice and in the Subapennine hills. Notwithstanding the moderate dimensions of this sheet, we shall

find in it the greatest number of sedimentary formations, and an extensive variety of eruptive rocks.

Sedimentary rocks. — The *micaceous schists*, or more correctly the schists *à sericite*, constitute the most ancient formation, and form a border round the coal basin of the Reyran. These rocks are soft and easily acted on by atmospheric agents, which impart to them a greenish tint; they possess but little quartz, and the development of the sericite is variable; in this manner they pass into true phyllades or argillaceous schist or clay-slate, and the transition is very distinct in the Maures, where this formation is of great extent. In the vicinity of the gneiss, a band may be followed, in which the sericite is largely developed and accompanied by minerals; garnets, staurotide, kyanite (*disthène*) posterior to the formation of the rock. Tourmaline and felspathic kernels are found in proximity with numerous veins of peginatite, which cross them.

The *Coal formation* covers them in the valleys of Reyran, Briançon and the Vernatèles; the northern part of the basin appears to contain only a single seam of poor coal, the outcrops of which are always near the lower limit of the formation, and these outcrops are only observed on the eastern border of the basin, where the strata are nearly vertical; above the seam of coal are fine sandstones, foliated and blackish, containing a few beds of coarser sandstone of a light colour. The same seam is worked at the mine of Vaux, where the average thickness is 2 metres; the fine grained schistose system, which covers the seam, is surmounted by a considerable mass of pudding-stone with

large pebbles, which occupies the greatest part of the surface, where the coal formation crops out. In the Southern part of the basin, we find under the pudding-stone, the schistose system which contains, in the upper part, a thick bed of bituminous schists, worked on the borders of Reyran, in the most Southern part of the basin.

In the North of the great Crystalline spur, which narrows the coal basin, outcrops of schist are found on the same level, mixed with thin veins of coal, the depth of which is not yet ascertained. In addition, we find on the Eastern border of the basin, and above the pudding-stone, a system of sandstone and schist, containing several seams of smith's coal.

This little coal basin is traversed by some important accidents. A fault, or a system of faults, parallel and near to each other, crosses it from North to South; this fault constitutes a boundary on part of the Eastern border of the basin, and the upper strata of the series meet the Crystalline schists; the thin seam of coal is hitherto found only in a strip spared by the fault, which, in the valley of Vaux, leaves the boundary in order to penetrate into the Coal formation, the greatest part of which is found to the West of this principal fault, and is rendered uneven by a system of faults N. W., trending perpendicular to the general direction of the strata, and accompanied by important outthrows, all in the same direction, the Southern extension of the strata bearing towards the East.

The Coal formation is also traversed by an eruptive rock, the dikes of which have taken the directions of the fractures just noticed. This rock has changed the character of the

sandstone and even of the coal itself, by impregnating both with silex and carbonate of lime; it consists essentially of triclinic felspar of an indeterminate nature, and of crystallized quartz. Its age is difficult to determine, and no shingle of the rock has hitherto been found in the pudding-stones below, or in the muschelkalk.

The Permian rocks are closely connected with the porphyries, the debris of which are closely united with those of the gneiss, and almost entirely constitute its formation; in the middle of these arenaceous layers, a mass of red schists may be followed almost without interruption, from the environs of Cuers as far as to Agay. To the West of Vidauban, they are distinctly seen to rest on the gneissose and porphyritic pebbly sandstone of the hill of Sainte-Brigitte, and all these facts lead to the conclusion that the conglomerates forming the vast mass of Mont Roquebrune are also lower than these schists. In the same manner, porphyritic shingle is found at the base of the schists in the ravine of Gargalong, between Saint-Raphaël and Agay, and in approaching the Estérel, these will be observed to rest on conglomerates and tuffs, which are also porphyritic. In general, these schists are sufficiently hard at the base to serve for flagstones, while the upper part is rich in blocks of limestone, of which the bulk and number have offered sufficient inducement to work them in some places at the foot of the Estérel.

The schistose stratum enables us to distinguish in the Permian formation, a lower and a higher series than the schists, and it is in the middle of the lower conglomerates that sandstones and psammites will be found intercalated: they have vegetable imprints, among which the Walchia

predominates; some fragments of silicified wood are also met with. At some points, near Adrets and in the vicinity of Blavet, to the West of Bagnols, the conglomerates appear destitute of porphyry, but this negative characteristic is of no value, since in the masses of Roquebrune and Vidauban, which are certainly posterior to the porphyries, we find beds also deficient in this particular; at the point of contact with these conglomerates, the subjacent strata, gneiss, mica-schist or coal are much reddened and deteriorated; the felspars become kaolin, and the micas lose their lustre and transparency.

Neither conglomerates nor breccia exist in the upper series, but only pudding-stone, which contains fragments of gneiss, mica-schist, porphyry and, in certain points, melaphyre. This series is well developed in the plain of Fréjus, on the coast, between Saint-Raphaël and Darmont; the pudding-stones are there separated by some argillaceous and micaceous beds, generally red.

True to its invariable characteristics, the *Trias* is subdivided into three periods or stages (*étages*); sandstone and quartzose conglomerate (grès bigarré), muschelkalk and saliferous and gypseous shales and sandstone (*marnes irisées* or irised marls). The *muschelkalk* is essentially calcareous and dolomitic; in the upper part, which is constituted by small beds of black limestone brightened by yellow, the lumachella or fire marble is met with, containing *Terebratula vulgaris* and *Encrinites liliiformis;* this calcareous part is very generally worked for the purpose of making lime; in the lower part, the muschelkalk becomes dolomitic, and rests on true cargneules.

Beneath these we find some beds of marl, green, yellow and violet, alternating with dolomites sufficiently thick to cause a water level, and finally, a thin layer of variously coloured sandstone, red and white, and containing much quartzose gravel. This system is immediately above other sandstones, with porphyritic kernels and argillaceous sandstone, which belong to the Permian formation, or the red schists, or even the gneiss in the environs of Bagnols.

Above the limestone of the muschelkalk is developed a system of *cargneules* and *marnes irisées*, with gypseous accumulations, that may be followed along the foot of the extensive terrace which exists from Tourrettes, by Grasse, to the environs of Cannes, although often concealed by the rubbish of the infralias or by the travertine; a large bed of limestone surmounts sandstones which contain indications of combustibles, everywhere observed above the gypsums, and associated with ferruginous nodules.

Green and black marls with limestone in thin layers beneath lumachella, immediately succeed them: *Avicula contorta* is found in this zone in which rise all the most important springs of the region; below the lumachella, calcareous layers are found, followed by dolomites of varied hues, and finally by large beds of extremely silicious limestone, sufficiently resistant to be worked for millstones; their constant mineralogical character renders them valuable for future investigations, and they contain some imprints of bivalves, which, as lower beds, should class them with the infralias.

A small bed of pink and green clay, separates the infralias from the Lower Oolite; the latter is composed of dolomites with broad facets, surmounted by branched siliceous

limestones; polypiers, remains of echini and pentacrinites are frequent, but fossils of a determinable character are only met with beyond the limits of the sheet. The dolomite sometimes occupies the whole thickness of the formation, and in this case, the silex is greatly altered and even dissolved.

The *great Oolite* commences with black clay, containing fossil wood, pyrites and gypsums; at the outcrops, these clays assume colours similar to those of the irised marls; whether alone, or mixed with the Pliocene clays, they supply materials for important manufactures of pottery; above them are calcareous marls filled with an *Ostrea*, similar to *Costata*, also *Pecten*, *Hinnites*, *Pholadomya* and *Trichites;* they pass insensibly into purer limestones of a yellowish white, with spathic points, containing *Rhynchonella decorata*, which furnish stone for ashlar and lime; then the limestone becomes dolomitic, grey and vacuolous.

In the environs of Biot, the dolomites directly support a white limestone or coral rag, with corals and Nerinæa, which belongs to the coralline and is the last term of the Jurassic series.

The *Cretaceous formation* is entirely wanting.

The *Tertiary formation* is represented by two stages : Eocene and Pliocene, in discord with each other and with the subjacent formations, which were worn into deep ravines previously to the Tertiary deposits. The Eocene is fossiliferous, and contains, with *Nummulites striata*, *Orbitoïdes sella*, *Rotulina spirulæa*, some *Schizaster* and *Echinocyamus*, in the sandstone composed of grains of quartz cemented by the limestone; the latter is more abundant in the schistose and

marly parts, at the upper part of the stage in which rotuline and orbitoïdes are found in great numbers. Under the nummulitic sandstone are coarse quartzose sands, coloured white and red, cemented by kaolin and containing great quantities of mica which demonstrate their granitic origin; thick conglomerates, with large Jurassic and Cretaceous elements, are intercalated in these sands, especially at their base, while at the top, under the nummulitic limestones, beds of siliceous limestone are found, probably a freshwater formation.

The *Pliocene* is constituted by blue marls, containing the well known fauna of Biot, surmounted by marlaceous limestones with *Amphystegina Haueri* and lumachellas with *Ostrea cochlear, Pecten dubius*, forming true faluns. Above these limestones, which form the counterforts of the hills to the West of the road from Antibes to Biot, some strips of water-worn pebbles are found, which appear to be the residue of the pudding-stone formation which covers the Subapennine marls, towards Villeneuve and Cagnes. To the Pliocene, have been assimilated the accumulations of white clays, that fill the clefts in the Jurassic formation N. E. of Cannes, which contain shingles of Tertiary and nummulitic sandstone, with Jurassic blocks. The Quaternary may be divided into two strata; the lower, composed of water-worn pebbles, sands and sandy clays, the other of greater extent, contains pebbles scarcely rounded, and covers the plains, while the lower stratum exists only in the valleys; the clays pass laterally to travertines, in the valleys of the Siagne, the Argens and the Riou.

At the embouchure of the Siagne, and in the basin of the

Brague, fine micaceous sands appear; these are also Quaternary, and are superposed on the Pliocene marls, from which they are separated by a bed of water-worn pebbles, with beds of shingles above. The osseous breccias of the Garoupe lighthouse belong also the Quaternary period.

Eruptive rocks. — The Cannes *gneiss* constitutes several formations, separated by rocks of a later date : one includes the hills which overlook Cannes and the mountains of Tanneron; a second comprises the environs of Bagnols, towards Saint-Paul to the West, and the Reyran to the East; a third takes in the formation of the Maures. The rock is composed of bronzed mica, forming almost continuous leaves, separated by a granular magma of orthite, oligoclase and quartz; the mica leaves are not strictly parallel, but blend in such a manner as to leave between them lenses, in which the crystals acquire more considerable dimensions; the distances between them are irregular, and they sometimes entirely disappear, particularly at the borders of the mass, and pass into true leptynites; under this form, the rock also constitutes thin veins in the schists.

In the mass of the Maures, the gneiss is penetrated by numerous veins of amphibolite, sometimes schistose, and throughout the region, by veins of pegmatite (frequently tourmaline); both these rocks pierce the schists, but the amphibolite appears of later date than the pegmatite.

The *red quartziferous porphyry,* with numerous crystals of red or white orthite, adularia or cat's eye, penetrates all the rocks, including the lowest strata of the Permian, which however, consist partly of its debris; schists may be found,

which, at a short distance, are superposed on porphyritic conglomerates.

These porphyries are characterized by the number of crystals they contain; though generally red, the substance varies much in respect of colour and tenacity; sometimes it appears to consist of microscopic crystals, sometimes it is amorphous, with few spherolites.

The *pyromeride* is posterior to the red schists and the porphyries, it appears distinctly in the region between the Theoulé and the road to Italy, where it rests on the conglomerates and porphyritic sandstones, in which are intercalated schists with impressions of *Walchia;* the schists are also intersected by veins of this rock, and the same superposition may be observed in the southern slopes of the Estérel, where a thick sandstone more or less schistose, with porphyritic shingle and dipping to the South, rests on the porphyry of the summits in order to pass under the pyromeride which extends to the base of the mass; this latter intersects the red schists of the plain in several points.

Under the appellation of *pyromeride*, is designated a rock always ribboned or banded on a large scale, containing but few quartz crystals, and the ribboning of which is produced by the alignment of globules varying in size from 1 centimetre to a very small fraction of a millimetre; the largest of these globules are found in the vicinity of the pitchstones of the neck of Grane; the pitchstones being only accidents of the pyromeride.

The globulous character of the rock disappears in thin veins, but the ribboned texture remains always visible.

The *melaphyre*, if under this name we designate tempor-

arily all the pyroxenic rocks traversing the Permian of the Estérel, is abundantly distributed there in the form of veins and thin layers or sheets; the sandstones of the plain of Fréjus and the coast, to the East of Saint-Raphaël, are traversed by veins of rock sometimes compact, sometimes spilitic; the grain of the rock is occasionally regular, or it assumes a porphyritic character, owing to the development of labrador crystals; but these sandstones also contain shingle of melaphyre with porphyries and gneiss; the age of these melaphyres is therefore perfectly determined. But this is not the case with those that form veins, either in the pyromeride, or in the red schists and porphyritic conglomerates, and which form above the latter, mamelons or thin layers that do not appear to have been covered.

The *blue porphyry* of the Romans forms part of an eruptive mass of small extent and variable aspect, in the neighbourhood of Darmont; in the western part of the formation, where the Roman quarry is situated, large crystals of oligoclase and bipyramidal quartz are disseminated in a bluish paste; to the East, the rock is entirely crystalline; hornblende (*amphibole*) forms crystals as fully developed as felspar, and quartz is less frequently met with; this granitoid variety is specially worked for flagstones.

The rock appears, in several points, to support the Permian sandstones, but the distinct nature of the sections shows that in different places it cuts the sandstones, the schists, and the melaphyres; the analogy of these rocks and of the dacites leads us to conclude that they belong to the Tertiary period.

Finally, in the environs of Biot and the Cape of Antibes,

andesite is found in veins and conglomerates, and has penetrated the nummulitic rock on which the conglomerates have spread, but is found in rounded fragments in the molasse.

The veins of fluor-spar in the porphyritic conglomerates, porphyries and gneiss, are only metalliferous in the latter; they then contain galena and blende; veins of sulphate of baryta, also metalliferous, and veins containing deutoxide of manganese, or simply ferriferous, in the environs of Biot and Antibes; a deposit of iron oligist and pyrites has been the object of investigation near Agay, and the dacites of the Darmont contain iron ologist and copper pyrites.

The geological explorations of the Antibes sheet were accomplished in 1875, 1876 and 1877, by M. Potier, engineers of Mines.

GIVET SHEET ON THE $\frac{1}{10000}$th.

The fragment exhibited of the Givet sheet on the $\frac{1}{10000}$th, includes the part from the frontier of Belgium on the North, to Fumay on the South. The following formations are found in this space of country, and are given in descending order as follows :

A. Recent mud and water-worn pebbles of the valley.

p Mud and pebbles of terraces and plateaux. — The mud is used for making bricks. At the base, it frequently contains irregular debris of ancient rocks (*argile à blocaux* of M. Dumont).

c' Rounded pebbles of white quartz, blocks of perforated siliceous sandstone (Lower Cretaceous? altered to the diluvian era).

c Sand, filling a cleft or pocket in the Devonian limestone (lower Cretaceous).

d^6 PSAMMITES AND SCHISTS OF EPPE-SAUVAGE. — The lower zone only of this formation is recognized on the Givet sheet, viz. the *schistes de Famenne* of Omalius d'Halloy. The two levels may be distinguished :

The lower, characterized by *Rhynchonella Omaliusi*, constitutes the hill of Fort Vignes; it contains calcareous nodules abounding in Orthoceres and Goniatites;

The upper, distinguished by *Rhynchonella Dumonti*, is seen on the borders of the Schloup.

d^5 FERQUES LIMESTONE. — Is divided into two zones :

d^5_b Schists containing *Cardium palmatum*. — Black schists very fissiles, and characterized by *Cardiola retrostriata* (*Cardium palmatum*), *Goniatites retrorsus*, *Bactrites*. They contain nodular masses of red marble (d^5_{br});

d^5_a Schists with *Rhynchonella cuboïdes*. — Greenish grey schists with beds intercalated with blue limestone (d^5_{ac}), which constitute a slightly projecting line on the rock. Similarly to the preceding stratum, these schists contain nodular masses of red marble (d^5_{ar}), disposed in the form of isolated peaks. Those of Fort-Condé and that worked at Frommelennes furnish examples. Principal fossils : *Rhynchonella cuboïdes*, *Rhynchonella semilævis*, *Pentamerus brevirostris*, *Camarophoria megistana*, *Camarophoria formosa*, *Spirifer Verneuilli*, *Spirifer euryglossus*, *Spirifer nudus*, *Spirifer Urii*, *Spirigera concentrica*, *Atrypa reticularis*. At the base, is a bed of schists filled with *Receptaculites Neptuni*, and in contact with the succeeding stratum, schistose limestones with *Spirifer Orbelianus*, *Atrypa reticularis* very voluminous, *Orthis striatula*, *Favosites Boloniensis*, *Alveolites subæqualis*, *Cyathophyllum cæspitosum*. In the Bois-le-Duc at Foische, there is a rock of dolomitic limestone with a vein of fluorine and galena.

d^4 GIVET LIMESTONE with *Strigocephalus Burtini*. — Black or bluish limestone, characterized by *Strigocephalus Burtini*, *Spirifer mediotextus*, *Cyathophyllum quadrigeminum*; worked as freestone at Trois-Fontaines,

as marble at Aubrive, opposite Vancelles and at Rancennes, as stone for lime, at Trois-Fontaines, Givet-Notre-Dame and Frommelennes.

d^3 RANCENNES SCHISTS. — Grey schists intercalated with beds of limestone (d^3_c). Numerous fossils : *Calceola sandalina*, *Rhynchonella angulosa*, *Pentamerus galeatus*, *Orthis eifeliensis*, *Spirifer speciosus*, *Cystiphyllum lamellosum.*

d^2 VIREUX SANDSTONE AND SCHISTS. — Are divided into four zones:

d^2_d *Coarse schists of Hierges.* — Two levels may by distinguished :

1. The upper, characterized by *Spirifer cultrijugatus* and *Rhynchonella Orbignyana*, contains some beds of limestone;

2. The lower, characterized by *Spirifer Arduennensis*, *Rhynchonella pila*, *Rhynchonella daleidensis*, *Chonetes plebeia*, *Pleurodyctium problematicum*, *Leptæna Murchisoni*, *Grammysia Hamiltonensis*, presents at its base some beds of greenish black sandstone, worked for flagstones, near Vireux and in the wood of Chenet.

d^2_a *Red schists of Chooz.* — Schists and red sandstone, without fossils. In certain beds, *Ripple-marks* and the impressions of drops of rain may be recognized.

d^2_b *Black sandstone of Vireux.* — Very quartzose sandstone, black or dark green. Furnishes excellent flagstones. Fossils scarce. *Pleurodyctium problematicum*, *Leptæna Murchisoni*, *Chonetes plebeia.*

d^2_c *Coarse schists of Montigny.* — Fossils very numerous : *Spirifer paradoxus*, *Rhynchonella daleidensis*, *Leptæna Murchisoni*, *Chonetes plebeia*, *Pleurodyctium problematicum*, *Grammysia Hamiltonensis.*

d^1 ANOR SANDSTONE. — Smoke coloured sandstone, without fossils (on the Givet sheet); worked at the village of Montigny.

d_1 MONDREPUIS SCHISTS. — Are divided into four zones :

d_{1d} *Variously coloured schists.* — Red or green; the colours form zones in zigzag, of different degrees of schistose character.

Bed of quartzite intercalated; one of them (Fétrogne mill) contains small crystals of discoloured felspar.

d_{1b} *Fossiliferous schists.* — Dark green schists, characterized by *Primitia Joncsii*, *Beyrichia Richteri*, *Tentaculites grandis*, *Orthis Verneuilli.*

d_{1c} *Arkose* or felspar grit. — Coarse grained sandstone filled, with felspathic matters changed to kaolin, alternating with beds of greenish schists worked for rubble stone.

d_{1d} *Fépin pudding-stone.* — Pudding-stone with large shingles and schistose cement. This deposit is local and irregular.

s Revin schists and quartzites. — Lower Silurian (Cambrian).

s' *Violet and green schists with Dyctionema*, worked as slates at Fumay and Haybes. Contain bed of white quartzite.

s'' *Black schists and quartzites.* — Black schists with numerous beds of quartzites often pyritiferous. At the base there is a bed of black slate, worked at Fumay (Rocroi road) and at Haybes.

The detailed geological explorations for the Givet sheet were executed by M. Gosselet, Professor of Geology at the Faculty of Sciences, Lille.

CANTAL FORMATION ON THE $\frac{1}{40000}^{th}$.

The central volcanic part of Cantal rests either directly on the gneiss and mica-schist or on stratified rocks of different thicknesses, of the Tertiary period.

The sedimentary deposits of the Tertiary are represented by conglomerates and Eocene clays, beneath marls and Miocene fossiliferous limestones.

Two principal Tertiary basins are visible in the Southern part of the Cantal formation, viz. those of Aurillac and Murde-Barrez. Others basins less important are seen at Laveissière, at Dienne, and near Saint-Flour. Among the strictly sedimentary deposits, the Pliocene formation is only represented by some breccias of small extent, but in which are found the osseous remains of great mammalia, which enable us to determine the epoch of the deposits in question.

The eruptive products are more important. They are divided into three categories of rocks : 1. Basalts (basic volcanic rocks); 2. plagioclasic trachytes (acid or intermediary volcanic rocks with triclinic felspars); 3. phonolites (rocks with monoclinic felspar, pyroxene and nepheline). In central Cantal, trachyte, properly so called, does not exist, i. e. volcanic rock in which monoclinic felspar predominates.

The plagioclasic trachytes are all at the base of the labrador; they may therefore be designated as *labradorites*.

The most ancient frequently assume the domitic structure; they contain a large proposition of sanidine, are almost always rich in sphene and especially in biotite; they furnish some obsidians and pass into the trachyte properly so called. They are seen at the bottom of the cul-de-sac of the valleys of the Cère, the Jordane and the Allagnon i. e. near the heart of the volcans.

The labradorites of the middle period constitute thick breccias, visible in all the valleys diverging from the plumb of Cantal. The labrador appears there nearly in the state of felspar in large crystals. The minerals associated with it are hornblende, pyroxene, apatite, nepheline and oxidulated iron; as in the lower labradorites, the felspar, which predominates in the state of microlite, is oligoclase. In a great number of these rocks, the pyroxene prevails in relation to hornblende.

The most recent labradorites constitute the summits of the greater part of the highest mountains of Cantal : Chavaroche, Puy-Mary, Pierre-Arse, Cantalon, etc. Each of these rocks is represented by compact beds, lavas in form of breccias and projected scoria.

The basalts also belong to three distinct formations; the lower basalt is deposited immediately upon the Miocene limestone; it is of a fine grain, rich in pyroxene and olivine, contains labrador microlites, pyroxene and oxidulated iron; it also possesses labrador and anorthite, in the state of large crystals; in certain localities, the felspars disappear, and it passes into peridotites. It is principally observed near Aurillac and in the upper part of the Allagnon valley.

The middle basalt is a rock with large crystals visible to the eye; and always rich in felspar. This basalt is found in the environs of Thiézac and Lascelle, between the valley of the Cère and that of the Jordane, and appears in the middle of the phonolites, at the foot of the Grioux mountain.

The upper basalt covers the high plateaux of the country, and is identical in composition with the lower basalt.

The phonolite is rich in monoclinic felspar; it contains microlites of pyroxene and almost always in large crystals, hornblende, pyroxene, sphene, biotite and haüyne; it contains more or less of nepheline, and passes into rock in which the mineral element is completely wanting. The mountains Grioux, Griounaux, Usclade and Roche-Taillade, are formed of this rock, which contains some lodes.

A bed of ashes appears in the middle of these various deposits, and is remarkable for the vegetable debris and impressions of plants observed in it. These plants belong to the flora of the lower Miocene. The deposit containing them, distinctly separates the middle basaltic and labradoric strata, from the upper strata formed by the same rocks. The principal deposits exist at Vic-sur-Cère, Peyre-

del-Cros, Saint-Vincent, Cheylade, and two different points of the valley of Fontanges.

The panel exhibited, comprises the Cantal formation; it is on a scale of $\frac{1}{40\,000}$th, and was obtained by an enlarged photograph from four sheets of the chart of the War Department, including Mauriac, Brioude, Aurillac and Saint-Flour. The explorations for the geological outlines and bearings, were made in 1876 and 1877 by M. Fouqué, Professor of Geology at the College of France.

GEOLOGICAL SURVEY OF MONT-DORE.

This survey was performed at the request and for the service of the general Council of the department of the Puy-de-Dôme. The Service of the detailed Geological Chart of France has undertaken to publish it at the expense of the department.

The work exhibited, comprises; 1. a geological chart; 2. a sheet of sections and profiles. Both are on a scale of the $\frac{1}{40\,000}$th, and are coloured in the same conventional tints.

The chart embraces the central part of the Mont-Dore formation, i. e. all the upper region of the formation, and the heads of the valleys descending from it. The topography is the reproduction of the minutes of the staff chart of the War Department, and the only additions consist of several roads formed after the completion of the latter. The relief is represented by curves of level, at distances of 10 metres according to the perpendicular, or, when the slope is excessive, of 20 metres; for every 40 metres, the curve is indicated by a thicker line.

The sheet of sections and profiles comprises four projections: two on a plane N. S., and two on a plane E.W. In order to trace each of them, a vertical cylinder was imagined, of which the generating points follow the watercourse of the two valleys in an opposite direction, nearly N. S. or E.W., and traverse the neck or ridge which separates them; the section thus obtained, was projected on a vertical plane N. S. or E.W., then the lines of apparent contour of the district, which are found on a single side of the cylinder, are repeated on the same plane. On these projections are figured the outcrops of hard rocks which are visible; the tuffs, which form the greatest part of the mass, have only been tinted in the parts intersected. The scale of heights is the same as that of lengths.

As before mentioned, the tuffs and trachytic conglomerates form by far the greatest part of the volcanic rocks of Mont-Dore. In the middle of these, solid layers are intercalated, presenting a series of rocks, of which the order of superposition is always the same, wherever they are found. They may be stated in the ascending order, as follows.

1. An intermediate rock between the basalt and the trachyte or even the phonolite, and passing to both, to which the name of *greystone* was given by Poulett Scrope, and which appellation it still retains (density 2,58 to 2,70);

2. A free basalt (density 2,89 to 3,08), passing sometimes to pyroxenic porphyries or to basaltic wackes;

3. A grey trachyte, slightly pumiceous, with large sanidine crystals (density 2,71 to 2,82), often extremely vesicular;

4. A porphyritic trachyte, with a paste most frequently green or violet, sometimes white and abounding in sanidine crystals (density 2,42 to 2,60);

5. A phonolite (density 2,47 to 2,56), of later date, certainly posterior to the grey trachyte.

The tuffs are often traversed by dikes formed of these various rocks; the beds of alunite in the ravines of Craie and Roc-Barbu are connected with these dikes.

A single stratum often presents rocks of very different character, at various points of its course; basalt passes to dolerite, grey trachyte to basalt, on one side, and porphyritic trachyte on the other, etc.

Leaving the central part of the formation, we find other basaltic lavas of more recent date than the trachytes; some of them proceed from cones of scoria, and appear nearly as recent as the lavas from the volcanos of the chain of Puys.

It is therefore impossible to continue the distinction, in the central volcanic rocks of France, of three series of distinct eruptions, characterized respectively by trachytes, basalts and modern lavas; the basalts, trachytes and phonolites form one continuous series, which connects two extreme types, and it must be admitted that they have been produced alternately from the most ancient eruptions to the most recent.

On the other hand, no vestiges are found on Mont-Dore, of an unique and central crater, whence the constituent rocks of the formation might have proceeded. It is more probable that they reached the surface by different fissures and orifices, frequently irrecognizable at the present time.

The volcanic mass of Mont-Dore rests on the granite, which is of a large grain in the Southern region, and finer to the North and East; on the South side it is not seen, and basaltic plateaux extend to the foot of Cantal. In the valley of the Dordogne the granite is separated from the tuff, at La Bourboule, by a great fault E. 28° N., which, with a slight turn, extends to the flank of Puy-Gros. This fault is accompanied by two others in an inverse direction. To the East of these faults, in the valley of the Dordogne, the granite rises to the altitude 700^{m}, while in the valleys to the North and West, it rises to the altitude 1 100^{m}. These differences of level are doubtless owing to other great accidents, also posterior to the appearence of the volcanic rocks of Mont-Dore, which may have influenced the relief of the formation to so great an extent.

The survey of Mont-Dore was accomplished by M. Amiot, engineer of Mines, in residence at Clermont-Ferrand, attached to the service of the detailed Geological Chart of France, and to that of the subterranean topography.

TERTIARY BASSIN OF THE S. W.

The panel exhibited, comprises sheets n° 180 Bordeaux, n° 191 the Teste-de-Buch, n° 203 Sore, n° 15 Mont-de-Marsan. It is only a fragment of the Tertiary basin of the S. W. or Sub-Pyrenean, which was shown at the Paris Universal Exhibition in 1878.

A section of the basin, extending from Auch to Mont-Marsan, has been added and prolonged as far as the sea, across the landes of Gascony and the dunes of the littoral.

The most salient features of the geological constitution of the S. W. plain are but imperfectly represented on the panel, but the section is adequate to giving a clear conception of the subject.

They may be divided as follows:

1. In this region, the Cretaceous and nummulitic strata form a series of undulations manifestly parallel to the axis of the chain of the Pyrenees, and uniformly present a side but slightly inclined in respect to the latter, and on the other hand, a very abrupt reverse in the opposite direction. Three of these great furrows are represented on the sheets exhibited. Commencing from the South, they are :

a. The Cretaceous point extending to the S. E. of Saint-Sever, between Hauriet and Fargues, and which is connected, in this direction, by the deposits of Gensac and Mauléon, with the masses of Aurignac and Ausseing, commonly known as the *Petites-Pyrénées.*

b. The protuberance extending from Roquefort (Landes) to the small farm of Bordères, commune of Laverdens (Gers) passing by La Pouchette, Le Gentilhomme, La Hiouère, Biereux and Créon.

c. The point of Villagrains, which occupies the upper part of the valley of Cabanac, and of which the second landmark is at Landiras, on the La Réole sheet.

2. The Miocene formation of the Tertiary period has been deposited in the compartments by this succession of undulations. It is there presented with an immense development and various characters, according to the region considered. Thus the lacustrine strata predominate in the North and

East, while the marine strata preponderate on the Western side.

3. The last are usually interposed in the form of wedges in the middle of the first. In plan, they take the form of a triangle, of which one of the sides is supported by the littoral, while the apex is situated in the interior of the formations, at a distance which becomes greater in proportion as they are more recent.

4. To this disposition, the only exception is constituted by the marine strata with *Ostrea crassissima* and *Cardita Jouanneti*, the deposit of which is manifestly posterior to that of the great lacustrine mass which covers the Agenais and the upper Armagnac. The sea, in which these strata were deposited, has formed deep indentations and ravines in the freshwater strata constituting the cliffs which are so prominent in the relief which meets the eye of every observer going from West to East.

The denudation has, nevertheless, left intact a few islets of lacustrine formation, which point to the middle of the marine sands, as is shown in the section.

Subsequent to the upheaval of the Pyrenees, which followed the formation of the Eocene strata, the partial demolition of the lacustrine strata by the sea, *Ostrea crassissima* is the most considerable and important fact observed in the structure of the tertiary basin of the S. W. It corresponds to a well defined division in the middle Tertiary strata, and separates those to which has been applied the qualification of oligocene, from the Miocene deposits properly so called.

5. The quartzose sand of the Landes is the highest Tertiary deposit in the S. W. region. In respect to the Miocene,

it assumes a complete independence, since it is found indiscriminately superposed on the various strata composing this formation; for this reason it has been properly referred to the Pliocene period. It may be observed on the section, that the sand of the Landes reproduces the disposition already noted, in the bearings of the strata with *Ostrea crassissima* in relation to the lacustrine deposits.

The special description devoted to the region of the S. W., explains in detail, the divisions introduced into the rocks constituting the formation of this region, and their assimilation to the strata which compose the Paris basin.

The geological outlines and bearings on the sheets exhibited were executed by MM. Jacquot, Inspector general of Mines, Director of the chart service; Linder, engineer in chief of Mines, at Alais. The Geological and agronomical chart of Gers and that of the Landes, by MM. Jacquot and Raulin have been utilized for this work.

The section was prepared by the Director of the Geological Chart Service.

XLIX

MICROGRAPHIC MINERALOGY.

The object of the work, entitled *Microcraphic mineralogy*, is the application of the microscope to the study of the constituent elements of the Crystalline rocks. It comprises descriptive text, forming a volume 4 to of 509 pages, and an atlas of 55 plates. Fifty-three of the principal types of the rocks of France are depicted and described independently of those in other countries. This work is a natural introduction to the geological description of districts in which the crystalline rocks are developed. For this reason, it has been thought proper to give it a place in the explanatory text of the detailed Geological Chart of France.

The authors of *Microcraphic mineralogy* are MM. Fouqué, Professor of Geology at the College of France, and Léon Michel, engineer of the Corps of Mines.

THE DISTRICT OF BRAY.

Under this title will be found a geological description of the small region of Beauvais, extending to a little beyond Neufchâtel, a region that possesses a preponderating influence in the structure of the plains in the North of France. The work forms a volume 4 to of 178 pages, to which is attached a geological chart of the region on the $\frac{1}{320000}^{th}$, accompanied by several plates.

In respect to the form, the geological description of the

Bray district may be considered as a specimen of a type definitively selected for publishing the explanatory text of the detailed Geological Chart of France.

The regional monography is the work of M. DE LAPPARENT, engineer of the Corps of Mines.

COMMISSION ON EXPLOSIVE GASES OR FIRE-DAMP[1].

By an Act of the French Parliament, dated the 26th March 1877, a Commission was appointed for the purpose of considering suitable means for preventing the explosions of fire-damp, which make so many victims in the coal-mines every year.

This Commission, which is composed of engineers and scientific men, has now been actively engaged for more than two years, in the fulfilment of its important task.

Aided by the advice of the most competent persons, the Commission, in the first place, met and discussed all the documents already available, and afterwards examined attentively the various methods and inventions recently proposed.

The Commission then proceeded to throw all possible light upon the subjects, from a practical and theoretical point of view, by instituting a series of experiments relative to the safety-lamps, explosive matters, ventilation and anemometrical apparatus, safety and physiological apparatus appertaining to coal-mines.

In addition to these proceedings, the Commission examined in detail the regulations actually in force respecting fire-damp in the mines of France, Belgium, England and Germany, and the results of their profound consideration of the subject are to be collected in a volume containing the principles to be consulted in working mines in which explosions of fire-damp are to be apprehended. In a few months, the Commission hopes to be in a position to present this volume to public notice.

[1] See collection of pamphlets among the documents of the School of Mines.

THIRD PART.

PUBLIC EDIFICES AND NATIONAL PALACES.

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PUBLIC EDIFICES AND NATIONAL PALACES.

This Department comprises all the public edifices and palaces (apart from those possessing historical interest), diocesan palaces, penitentiary establishments, military buildings or barracks, and the departmental and communal edifices.

This service is attached to the Ministry of Public Works, and the direction comprises two divisions :

The public and official edifices;

The national palaces.

The duties belonging to these two divisions are nearly the same, in all that relates to the buildings, the character of which is indicated by the name. These duties may be summarized as follows :

Study and preparation of new projects. Examination of estimates, prices, conditions of contract. Adjudication and preparation of agreements. Ordering works of art for the decoration of public buildings. Preparation of budgets, acts and decrees. Expropriation for public purposes, acquisitions and transfers. Authorization of expenditure for new works, for works of maintenance and repairs on a small or large scale. Execution and superintendence of works. Inspection and revision of accounts, and documents of expenses relative to all the works. Examination of contractor's claims. Appeals to the Council of the Prefecture, and the Council

of State, in cases of litigation or disputed claims. Regulation and settlement of accounts and expenses. Keeping an account of the balance at the disposal of the Ministry. Situation of markets.

The department of national palaces is also specially occupied with the administration of the national property; the furnishing of the palaces; installation, in the case of fêtes and official ceremonies; inventories and moving of furniture; expenses relative to furniture; care and inspection of palaces, parks and gardens; control and revision of accounts and expenses.

On all general questions, relating to these matters, the Minister consults the high Board or Commission for public edifices and national palaces, and on technical questions, the general Council of public buildings.

HIGH COMMISSION OF PUBLIC EDIFICES AND NATIONAL PALACES.

The chief or high Commission was appointed by a decree of the 28th May 1878, and takes cognizance of all important questions relating to edifices and palaces. It takes into consideration the propriety of their erection, in the first instance; the use to which they should be appropriated; the choice of sites, reconstructions, enlargements, isolations, etc. When the commission has decided upon these general and preliminary points, the projects are submitted to the Council of Government edifices and national palaces.

GENERAL COUNCIL OF GOVERNMENT EDIFICES.

This Council examines technically, the plans and estimates of works to be executed by the Department of public edi-

fices and national palaces, also the projects transmitted to the Minister of Public Works, by the different ministerial departments, requesting the consideration or advice of the Council; also the disputed claims relative to building works.

In addition to the Minister or Under-Secretary of State for Public Works, President, and to the Director of public edifices, member ex officio, the Council consists of:

Four general inspectors, permanent members of the Council;

Four architects, temporary members, nominated for two years;

Two auditors, architects and formerly gainers of the prize of Rome[1];

One secretary, charged with keeping the minutes of the Council, and the preparation of its conclusions;

One controller, charged with the inspection of the estimates accompanying the projects submitted to the Council.

Besides participating in the labours of the Council, the Inspectors general are charged with the inspection of works of maintenance, new buildings and repairs, and no undertaking is commenced without their advice.

ARCHITECTS.

The works are executed under the direction of architects appointed by the Minister, and usually selected from those

[1] Prize of Rome (*prix de Rome*). A student gaining this distinction, is sent to study at Rome for a certain period, at the expense of the Government. It is awarded to each of the successful competitors in Architecture, Painting, Sculpture and Music. (*Translator.*)

who formerly distinguished themselves at the « École des beaux-arts », and chiefly among those students sent to Rome by the French Academy, and those possessing diplomas of merit.

They are remunerated according to the sum of the accounts, after inspection and verification. This remuneration is fixed at:

4 per cent on works of maintenance;

3 per cent on new works or considerable repairs.

PERSONNEL OF THE SUPERINTENDENCE.

The architects have under their orders, staffs, of which the personnel is also appointed by the Minister, and which are ordinarily composed of:

One inspector,

One sub-inspector,

One clerk of the works,

One examiner.

This personnel may be augmented or reduced, according to the importance of the works. The inspectors, sub-inspectors and clerks of works, receive fixed annual salaries varying from 1 800 to 3 000 francs. It is only in exceptional cases, and when the work is of a very important character, that the maximum of 3 000 francs is exceeded.

The remuneration of the examiner is fixed at 1 per cent, and is proportional to the amount of the expenditure, after inspection and verification.

The inspectors assist the architect in the study of the working details of the plans, and in the general superintendence of the works; the sub-inspectors are specially charged

with the memoranda of the work done, and the accounts generally.

The clerk of works is occupied with the men and the operations; he attends to the arrival and placing of materials, and the proper execution of the work.

The examiners are occupied during the whole of the undertaking, but chiefly when the contractors have sent in their accounts. They check them off on the spot, and ascertain that all quantities, measures, and methods are exactly as in the account; they also satisfy themselves that the prices are those which served for the base of each adjudication, or each commission.

A commission of examiners is employed by the administration, to establish a list of the prices of all descriptions of work connected with building, and this list is consulted in regulating the accounts, after deduction made for abatements agreed upon.

The works concerning the public edifices and national palaces are divided into three categories: works of maintenance; repairs on a large or small scale; new works.

WORKS OF MAINTENANCE OR KEEPING IN REPAIR.

The greater part of the buildings under the care of the department of public edifices are situated in Paris or the environs; the maintenance of the dépôts of stallions belongs to the Ministry of Agriculture and Commerce.

These edifices are divided into four great divisions of inspection, and each division contains four circumscriptions.

At the commencement of the yearly receipts and expenditure, the proposals presented by the architects, for works

of maintenance in the buildings entrusted to their charge, are transmitted to the administration, and examined by the Inspectors general. After this examination, the sum allotted for expenditure is distributed among the different establishments by ministerial decision.

In the course of the year, works are executed conformably to this decision, under the direction of the architects.

REPAIRS ON A SMALL AND LARGE SCALE.

GREAT WORKS.

For the execution of these two different categories of works, the method of proceeding is almost the same; there is no difference in the progress of the operations, the book keeping, or the verification and liquidation of accounts. Only in the case of new works, the administration, to which the edifice will appertain, is consulted, and requested to furnish a list of the purposes for which the building may be required, in order that the structure may be adequate to them, and give entire satisfaction.

This programme is studied in detail and approved by the Minister in question; it is then transmitted to the Minister of Public Works, who appoints an architect of his own choice, to take it as a base for the plans and specifications.

These being finished, are transmitted to the Minister who furnished the list of requirements, in order that he may satisfy himself that all the conditions therein contained, are properly fulfilled, and he then approves the project if expedient. For unimportant and considerable repairs, the architect charged with the maintenance of the edifice, furnishes the plans and specifications.

In a similar manner, the plans for new works are submitted to the general Council of national edifices, and examined from an architectural and financial point of view. When the plans are accepted by the Council, the Administration prepares a bill to be laid before Parliament, for the purpose of obtaining not only the approval of the projected work, but a vote of the sum necessary for its execution.

In the case of new buildings or additions, a bill is always necessary, but the cost of repairs on a small or large scale, is sometimes, in exceptional instances, defrayed from the ordinary budget of the Minister of Public Works.

When the Administration is assured of the necessary grant from Parliament, proceedings are commenced. Tenders are invited, after submitting the following particulars for the approval of the Minister:

General conditions of contract,

Particular conditions of contract,

List of prices,

Plans, sections, elevation,

Estimates.

At the commencement of operations, the agency or staff of management is constituted by a ministerial decision, as before mentioned in the article PERSONNEL OF THE SUPERINTENDENCE.

In proportion to the progress made, the contractors send in their account of the work executed, with memoranda relating thereto.

These accounts are made in triplicate; one, which is stamped, only contains a summary of the work, and is subsequently sent to the Audit office (Cour des comptes).

The accounts are verified by the examiner, and then transmitted to the Board of Direction of public edifices and national palaces, where special controllers examine the work of the examiner, correct if necessary, and finally pass them; payment is then ordered to be made to the parties concerned.

At the settlement of the accounts, all complaints are heard and examined by the Council of public edifices, and if the contractor making complaint does not accept the decision of this Council, he can take the case before the Council of the Prefecture, and in last resort, before the Council of State, from which there is no appeal.

To complete this summary exposition of the functions of the Department of Public Edifices and National Palaces, a list is subjoined, containing the names of all the buildings and edifices of which the maintenance and repairs are entrusted to its management.

EDIFICES AND PALACES

COMPRISED

IN THE DIRECTION OF PUBLIC EDIFICES AND NATIONAL PALACES.

PUBLIC EDIFICES [1].

	MM.
Observatory	Bouchot.
Ministry of Public Instruction and the Fine Arts	*Idem.*
Monument to Marshal Ney	*Idem.*

[1] Where the edifices or institutions are *exactly* analogous to those of the same kind in England, the English equivalent is given; otherwise the literal signification of the French words is retained. (*Translator.*)

	MM.
Higher Normal School[1]	Bouchot.
Odéon Theatre	*Idem.*
Deaf and Dumb Institution	Monge.
National School of Mines	Valler.
College of France	Lepreux.
Church of Sainte-Geneviève	Le Deschault.
School of Design	*Idem.*
Library of Sainte-Geneviève	Jourdain.
Court of Cassation	Coquart.
School of the Fine Arts	*Idem.*
Palace of the Institute (French Academy)	Moyaux.
Meridon Observatory	*Idem.*
Monument of Henri IV	*Idem.*
Palace of Orsay	*Idem.*
School of Pharmacy	Laisné.
Polytechnic School	Henry.
École des Ponts et Chaussées (College of Engineers)	Faure-Dujarric.
School of living Oriental Languages	*Idem.*
Ministry of Public Works	Trouillet.
Ministry of Agriculture and Commerce	Brune.
Ministry of the Interior	Pigny.
Ministry of Marine (Admiralty)	*Idem.*
Ministry of Justice	Destailleurs.
Ministry of Foreign Affairs (Foreign Office)	Mauss.
Ministry of Posts and Telegraphs (Post Office)	Rigault.
Institution for Blind Children	Abadie.
Opéra-Comique Theatre	Crépinet.
Opéra-Comique Scene Repository	*Idem.*
Church of the Invalides (military pensioners)	*Idem.*
Marble Depôt	Debressenne.
Post Office	Guadet.

[1] Training College for Teachers and Professors. (*Translator.*)

	MM.
Arc de triomphe de l'Étoile (Triumphal Arch)..	Normand.
Obelisk	*Idem.*
Vendôme Column	*Idem.*
Palace of Industry (Exhibition Building)	Dutrou.
Grand Opera	Garnier.
Opera Scene Repository, rue Richer	*Idem.*
Conservatory of Music	*Idem.*
Chapel of Louis XVI	Chabrol.
Conservatory of Arts and Trades	Ancelet.
Porte Saint-Martin[1]	*Idem.*
Porte Saint-Denis	*Idem.*
Column of July	*Idem.*
National Library	Pascal.
Monument of Louis XIV	*Idem.*
National Archives	Leclerc.
Museum of Natural History	André.
Library of the Arsenal	Th. Labrouste.
Monument of Louis XIII	*Idem.*
Charenton Lunatic Asylum	Diet.
Veterinary School at Alfort	*Idem.*
Palace of the Trocadéro	Davioud, Bourdais.
Château of Saint-Germain	Lafollye.
Sèvres China Manufactory	Desbuisson.
Veterinary School at Lyons	Sainte-Marie Perrin.
Veterinary School at Toulouse	Laffon.
Deaf and Dumb Institution at Bordeaux	Labbé.
Deaf and Dumb Institution at Chambéry	Revel.
Miners' School at Saint-Étienne	Boulot.
Mont Genèvre	Chaudier.
Boulogne Column	Bouloch.
Dépôt of stallions at Le Pin	Arnoul.
Saint-Lô Dépôt	Kanapell.

[1] This and the Porte Saint-Denis are triumphal arches. (*Translator.*)

	MM.
Blois Dépôt	de Lamorandière.
Lamballe Dépôt	Guépin.
Pompadour Dépôt	Lafollye.
Pau Dépôt	Lévy.
Perpignan Dépôt	Vignol.
Cluny Dépôt	Giroud.
Aurillac Dépôt	Aiguesparse.
Annecy Dépôt	Ruphy.
Rodez Dépôt	Pons.
Montier-en-Der Dépôt	Descaves.
Angers Dépôt	Chesneau.
Besançon Dépôt	Ducas.
Rosières Dépôt	Morey.
Hennebont Dépôt	Halouis.
Compiègne Dépôt	Thierry.
Libourne Dépôt	Labbé.
Villeneuve-sur-Lot Dépôt	Gilles.
La Roche-sur-Yon Dépôt	Loquet.
Tarbes Dépôt	Larrieu.
Saintes Dépôt	Rullier.

NATIONAL PALACES.

Palace of the Tuileries	Lefuel.
Palace of the Louvre	*Idem.*
Palais-Royal	Chabrol.
Gobelins Manufactory	*Idem.*
Palace of the Luxembourg	Gondoin.
Palace of the Élysée	Debresenne.
Alma Mews	*Idem.*
Magazine of National Property	*Idem.*
Palace of Versailles	Guillaume.
Palace of Trianon	*Idem.*
Château of Rambouillet	Joly.
Sheep Farm of Rambouillet	*Idem.*

	MM.
Grignon Agricultural School	Joly.
Palace of Fontainebleau	Boitte.
Palace of Compiègne	Thierry.
Parterre and Terrace of Saint-Germain	Lafollye.
Château of Pau	Lévy.
Château of Saint-Cloud	Desbuisson.
Beauvais Manufactory	Auxcousteaux.

NATIONAL OPERA.

Portfolio of photographs.

By a decree of the 29th September 1860, the construction of a new Opera house was declared a work of public utility, and a competition was opened by a decree of the 29th December following. This competition was to terminate on the 31st January 1861.

On the 1st June 1861, the plan prepared by M. Charles Garnier was unanimously selected.

The architect commenced the undertaking immediately.

Ths first stone was laid on the 21st July 1862.

In the course of the first year, the progress of the work was much impeded by unforeseen difficulties in respect of pumping the water from the foundations; and during the years 1870-1, political events delayed the building operations, but the destruction of the Opera house in the Rue Le Peletier, by fire (28th October 1873), gave a fresh impetus to the works.

The inauguration of the new theatre took place on the 5th January 1875.

The superficial extent of the new Opera is 11 237^{m},75, the cube is 42 866 cubic metres.

The cost amounted to about 35 millions, the value of the ground not included.

The theatre contains 2 100 seats.

The materials employed were of the finest and most solid description (marble, granite, enamel, mosaic, bronze, etc.), and in the decorative part of the work, the architect was aided by the most distinguished artists.

In sculpture :

MM. Carpeaux, Guillaume, Jouffroy, Perraux, Chapu, Dubois, Falguière, Gumery, Ollivier Cabet, Moreau, etc.

In painting :

MM. Baudry, Barrias, Delaunay, Pils, Lenepveu, Gustave Boulanger, etc.

Since the inauguration of the Opera, the Ministry of Public Works has finished the Glacier gallery, and has converted all the central part of the west lateral façade into a library and museum, in which large saloons are reserved for the chief of the State.

This library, and the museum of designs, costumes, and models, will shortly be opened to the public.

COURT OF CASSATION.

Portfolio of photographs.

The Court of Cassation was instituted the 12th and 20th of August 1790, and took possession of that part of the Pa-

lace of Justice, where formerly the Parliament of Paris held its sessions. The Court, at the present time, occupies nearly the same place.

During the Terror, the sittings were held in the School of Law, but on the 6th Messidor, year III (25th June 1795), the Court was restored to its former locality and a decree of the 8th Floreal, year XII (28th April 1804) conferred upon it the name of Court of Cassation.

The space allotted in the Palace of Justice, being inadequate to the requirements of the Court, the building was enlarged, and a third hall built in 1828, on plans prepared by M. Huyot, the architect.

At the death of M. Huyot, his successor, M. Alphonse de Gisors, executed various works of importance, among which may be noticed the restoration of the part called the gallery of Saint-Louis.

In 1836, M. Le Normant replaced M. de Gisors.

This architect prepared the plans and specifications for the reconstruction of the Court of Cassation, which were completed by M. Duc, who succeeded him on the 15th January 1862.

In 1870, the Court of Requests, the private rooms of the judges and barristers, the Clerk's Office and the Library, were finished for the use of the Court.

During the events of 1871, part of the Palace was burned, and in particular, that portion of the Court of Cassation, which fronts the quay.

It was necessary to rebuild it, and the estimate was, at the commencement, fixed at 3 812 178 francs, but was subsequently augmented to 6 500 000 francs.

In 1877, the reconstruction of the part that had been burned, was terminated, and the Court was once more installed in the building, the Criminal Court being completed at the same time.

Up to the present time, the sums successively expended upon these buildings amount to a total of 6 millions.

It only remains to complete the fittings and decoration of the large court and its dependencies. This work is confided to M. Coquart, architect, successor to M. Duc whose death took place in 1879.

NATIONAL LIBRARY.

Portfolio of photographs.

At the present day, the National Library occupies the site of the great Palace Mazarin, in which it was placed by the Regent in 1721.

The origin of this Library may be traced to the early times of the French monarchy, although Charles V must be considered as the real founder. His successors added to the royal collection, which was first placed in the Louvre, afterwards taken to Blois under Louis XII, and subsequently to Fontainebleau under François I.

In the reign of Henry IV, considerable additions were made to the Library, which was installed in the College of Clermont, and at a later date, in the convent of the Cordeliers. During the reigns of Louis XIII and Louis XIV, it was enriched by many printed works and manuscripts, and Colbert ordered its removal to some houses near his man-

sion in the Rue Vivienne; and finally during the minority of Louis XV, it was definitively installed in the Palace Mazarin, in which building, works of considerable importance were projected and the execution was confided to Robert de Cotte.

The obligation to send to the authorities a copy of every work printed in France, and the acquisition of numerous private collections of books, especially the deposit during the first Republic, of many books belonging to religious institutions, rendered the locality quite inadequate to the increasing requirements of the Library.

On different occasions, the question of reconstructing the edifice in another place was brought forward, but this idea was abandoned, and the project of enlargement adopted in preference.

M. H. Labrouste, whose construction of the Library of Saint-Genevieve was a great success, was commanded by Government to prepare plans for the enlargement of the building. This work was commenced in 1858, and the principal part is now finished.

The new buildings include all those extending from the Rue Neuve-des-Petits-Champs to the Rue Colbert, with a return wing at each street.

Besides the large rooms allotted to the pamphlets and papers, there is a vast central hall, communicating directly with the reading room, and in which are arranged more than 800 000 volumes.

The arrangements of the reading room are remarkable for their excellence, and it is one of the most elegant specimens of iron-work hitherto constructed.

M. Labrouste was also engaged upon that part of the buil-

ding which fronts the Place Louvois, but he died in 1875, before the completion of his work.

He was replaced by M. Pascal, formerly a successful competitor for the prize of Rome (prix de Rome). This architect has finished the interior fittings of the part fronting the Place Louvois, and superintended the construction of the building, where it faces the Rue Colbert, on plans prepared by his direction.

At the present time, M. Pascal is commencing the restoration of the building at the end of the court of honour, (*cour d'honneur*) in which the great public reading room is to be established. The accomplishment of these works has necessitated an expenditure, which at the present date, amounts to about 22 millions of francs.

Notwithstanding all these enlargements and improvements in the buildings of the National Library, the want of space continues to increase, and it is not difficult to foresee that, in a short time, fresh additions will be indispensable.

In addition to which, the necessity of completely isolating the building from the adjoining houses, becomes more apparent every day. The acquisition of these tenements would not only give a great additional space of ground to the Library, but it would also have the effect of removing, or at least obviating, the danger of fire, a peril by which at present it is continually menaced, owing to the various occupations carried on in these houses.

A bill has been brought before the Chamber of Deputies, to obtain the sum necessary for the purchase of these tenements, and there is reason to hope that this question,

which is of such deep moment to the learned world, will soon be satisfactorily decided.

PALACE OF THE TUILERIES.

PAVILIONS OF FLORA AND OF MARSAN.

Portfolio and photographs.

In this notice, we shall not speak of the Palace itself, which has not been rebuilt since its destruction by fire in 1871, but shall give a short account of the pavilions of Flora and of Marsan, both of which were burned at the same time. One of these buildings was only partially destroyed, while the destruction of the other was complete; the galleries that connect them with the Louvre were also consumed, but, with the pavilions, they have been restored since 1871.

The pavilion of Flora and the gallery joining it were commenced under the reign of Henry IV, by Ducerceau, from 1595 to 1608.

This part of the Tuileries, as indeed the Palace itself, has only been inhabited for short periods of time, by the different monarchs in succession; and it was not until the reign of Napoleon I, that the Palace commenced to assume the character of a permanent residence, and was subsequently occupied by the sovereigns and their courts. The gallery that connects the pavilion of Flora with the Louvre, was for many years an integral part of the Museum of the Louvre. But, similarly to that of the pavilion of Flora, the foundation bottom was very defective, and during the first years

of the present century, this circumstance caused a sinking of the buildings on the side of the quay. Attempts were made to consolidate the structure by means of iron-work, but this expedient failed to arrest the sinking movement, and, in 1861, it was decided that the gallery, together with the pavilion of Flora, should be reconstructed.

New plans were prepared, and the works were executed by M. Lefuel, architect, from 1861 to 1869; the cost of the structure amounted to about 15 millions of francs.

In 1871, these constructions, which had just been completed, were seriously damaged by fire; since that period they have been restored, and are, at present, temporarily occupied by the Prefecture of the Seine.

The pavilion of Marsan was originally constructed in the reign of Louis XIV, by the architect Levau, and the gallery adjoining, which fronts the Rue de Rivoli, was built by Percier and Fontaine, architects, during the reign of Napoleon I.

These parts of the Palace have been successively occupied, under the same conditions as the pavilion of Flora, and in 1871, they were also completely destroyed by fire.

The works of reconstruction were immediately commenced under the direction of M. Lefuel, and at the present time, the exterior is entirely finished.

The principal sculptures of the two pavilions of Flora and de Marsan, were executed by MM. Carpeaux, Cavelier, Cranck, Bonassieux, Barrias, Delaplanche, etc.

SCHOOL OF THE FINE ARTS.

Portfolio of photographs.

The School of the Fine Arts (*École des beaux-arts*) occupies a part of the site of the old convent of the Petits-Augustins.

In 1790, this convent was appropriated to the Museum of French works of Art, but it was only in 1816 that the School of the Fine Arts was definitively settled there; previously to that time, lectures and competitions took place in the buildings of the French Academy.

The first constructions, necessary for the various divisions of the School, were executed by M. Debret, architect, and the Minister of the Interior laid the first stone on the 3rd of May 1820.

In 1833, M. Duban, architect, succeeded M. Debret and completed the structure as it now stands. He constructed the palace at the end of the court of honour, and in which are collected on the ground floor, models of the antique, and on the first floor, the vast apartments occupied by the Library.

M. Duban also prepared the plans and directed the works of the façade of that part of the building which fronts the Quai Malaquais. In this portion of the structure, the great Exhibition Hall (salle Melpomène) is situated, and on the first floor is another great hall, which is also used for exhibitions.

With the view of increasing the space allotted to the

gallery of models, the interior court of the palace has been covered with glass and converted into a vast hall, in which are collected the finest specimens of antique sculpture and architecture. This work was commenced by M. Duban, who died in 1870, leaving his work unfinished. It has since been completed by M. Coquart, architect, formerly successful competitor for the great prize of Rome (*prix de Rome*), who succeeded M. Duban as architect of the School.

Since the completion of the glass court, M. Coquart has restored the chapel of the old convent of the Petits-Augustins, for the purpose of installing in it the museum of the Renaissance, and, owing to the taste and discrimination exercised in the fittings and arrangements, this chapel is now one of the most interesting parts of the School.

These successive enlargements and improvements are, however, far from being adequate to the requirements of the School. The number of students increases every year; new courses of lectures are established; the studios are insufficient in number; the competition rooms and the lodge buildings are limited in accommodation, and no longer equal to the increasing needs of the institution. The Government therefore commissioned M. Coquart to prepare a plan for the enlargement of the building, and it is at present under the consideration of Parliament.

The execution of this plan will include the acquisition of several houses, and the construction of vast buildings, in which the lecture rooms and studios will be located, and this arrangement will allow all the old buildings to be devoted to the purpose of galleries for the reception of models and works of Art.

CONSERVATORY OF ARTS AND TRADES.

Portfolio of photographs.

The Conservatory of Arts and Trades was instituted by decree of the National Convention dated 19th Vendemiaire, year III (10th October 1795) and has occupied from the 12th Germinal, year VII (2nd April 1799), the buildings of the Priory of Saint-Martin-des-Champs; this establishement is bounded on the East by the Rue Vaucanson, and until 1862, was surrounded, on the other three sides, by private houses, which completely stopped its development, and at the same time constituted a permanent risk of the destruction by fire of the valuable collections contained therein.

By order of the Government, a plan was prepared in 1860 by M. Vaudoyer, architect of the building, and the execution of the works of isolation and enlargement were commenced in 1862.

The cost of the acquisition of the houses in the Rue Saint-Martin and the Rue Réaumur, and of the continuation of the buildings on the site of the properties acquired, was estimated at the sum of 8 millions of francs; and in fact, the acquisitions have involved an expense of 4 500 000 francs, and the constructions 3 500 000 francs.

The edifice is now completely isolated, on the side of the Rue Saint-Martin, and partly on that of the Rue Réaumur; the buildings including laboratories, an amphitheatre, department for industrial drawings and designs, and accom-

modation for the personnel of the administration, were built in these two streets, and are now delivered to the Conservatory.

M. Vaudoyer died in 1872, and was succeeded by M. Ancelet, formerly successful competitor for the great prize of Rome, who continued the buildings as far as the Rue du Vert-Bois; but the above-mentioned grant of 8 millions of francs being exhausted, the operations are suspended for the present. In order to complete the isolation and enlargement of the edifice, it will be necessary to acquire the houses situated in the Rue du Vert-Bois and the Rue de Breteuil, and replace them by buildings for new galleries.

The Conservatory would then be completely isolated, and would present a remarkable and striking ensemble, comprising numerous galleries, where models of industrial and agricultural machines are collected; amphitheatres for lectures; a library of more than 20 000 volumes, open to the public, morning and evening; a department where designs of all the machines are preserved, patents and trade marks; in addition, it would include the Agronomic Institution, a higher class agricultural school, instituted by the Act of the 9th August 1876, and temporarily installed in the buildings in the Rue Réaumur, until the new buildings should be completed.

PALACE OF THE TROCADÉRO.

Portfolio of photographs.

The palace of the Trocadéro is situated on the hill of Chaillot, fronting the Seine.

It was constructed on the occasion of the Universal Exhibition of 1878, by MM. Davioud and Bourdais.

The superficial extent of the building is about 14500 square metres.

The outlay was about 9 1/2 millions, or 650 francs per square metre.

It comprises : a central building, containing a great hall, 50 metres in diameter, and exhibition and promenade galleries; this part is used for fêtes and concerts;

To the right and left are buildings called conference halls, 25 metres by 15, the ground floors of which are arranged as two principal vestibules forming the entry to the palace.

Then two long curvilinear wings, containing exhibition galleries, each measuring 170 metres in length.

Lastly, two pavilions at the extremities.

The declivity of the surface admitted of the formation of special entrances, under these pavilions, giving access to the garden.

In front of the galleries of the wings, is a colonnade, which serves for a promenade.

This gallery overlooks the West of Paris.

The palace was commenced on the 1st November 1876, and completed for the Exhibition on the 1st May 1878.

CASTLE OF PIERREFONDS[1].

Portfolio of photographs.

The restoration of the Château of Pierrefonds was undertaken in 1858, by order of the chief of the State. M. Viollet-le-Duc, the erudite and skilful architect of historic edifices, was charged with the work of restoring this castle.

The cost of the entreprise, when completed, will amount to 5 millions.

Up to 1870, more than 4 millions were expended, of which about three millions were defrayed from the civil list, and the fourth from the funds allotted to the restoration of historic edifices.

This castle is one of the most complete and curious specimens of the feudal architecture of the middle ages, and dates from the first years of the XIV^th^ century.

It was built by order of Louis, duke of Orleans and brother of Charles VI.

In this magnificent residence, the attention is particularly attracted to the system of defence adopted at the close of the XIV^th^ century. The fortress could only be taken by the assistance of artillery; to all other means of attack, it was impregnable.

In 1616, the castle was besieged and partly destroyed

[1] The word *castle* is here used according to the true English signification, i. e. a fortress or place of defence. The French word *château* is more comprehensive in its meaning. (*Translator.*)

in this manner, and in the following year, was dismantled by order of the Government of Louis XIII.

During the Revolution, the castle of Pierrefonds was sold as a national property.

In 1813, Napoleon I repurchased Pierrefonds, and it was again numbered among the dependencies of the forest of Compiegne.

The works of clearing and of restoration were commenced, as before mentioned, at the beginning of 1858. The donjon, the castle, and all the exterior defences have resumed nearly their primitive appearance.

The undertaking confided to M. Viollet-le-Duc may therefore be considered as nearly terminated. Some masonry and earthworks of the approaches to the castle, are all that remain to be executed.

Since the death of M. Viollet-le-Duc, these have been continued by M. Ouradou, his son-in-law, the architect of historic edifices.

CHÂTEAU OF SAINT-GERMAIN-EN-LAYE.

Portfolio of photographs.

In conformity to a decree of the 8th March 1862, it was decided that the Château of Saint-Germain-en-Laye should be repaired and appropriated to the reception of a Gallo-Roman Museum, and the work of restoring this remarkable edifice was undertaken from that date.

According to the historians of Saint-Germain, this château was selected by the kings of France for their resi-

dence, as far back as the xiith century. From Philip Augustus to Louis XIV it was almost constantly inhabited by royalty. Saint Louis ordered the construction of the curious and beautiful chapel in the Southern façade, the restoration of which is now almost completed.

But it was in the reign of Francis I, that the Château of Saint-Germain attained the development and importance of which the newly restored buildings enable us to form a correct appreciation.

Louis XIV added the five large pavilions, which were still existing before the work of restoration commenced. The construction of these buildings compelled the king to leave the palace, and he abandoned it definitively in 1682, to take up his residence at Versailles.

In 1809, Napoleon I established a cavalry school in the château.

In 1836, the military penitentiary was installed in the building, and continued there until 1855, when the old Château was again placed under the direct control of the State.

Previously to the commencement of the operations, M. Millet, the architect, who was appointed to the work, propounded the question with respect to the restoration of the building, if it should be restored in the style of Francis I, or if the pavilions under Louis XIV should be retained.

A commission, presided over by the Minister of State, was appointed to decide upon this matter, and it was unanimously resolved that the edifice should be restored in accordance with the style of Francis I, and consequently

that the pavilions erected under Louis XIV, should be demolished.

The plans and specifications prepared by M. Millet, were entirely approved by the commission.

From 1862 to 31st December 1879, a sum of 2608000 francs was expended.

In respect of the work, M. Millet followed the example of the architects of the Renaissance, in having every stone perfectly cut and prepared, before being laid.

Unfortunately this eminent architect died before the completion of his work.

In 1879, M. Lafollye, the architect of historic edifices, succeeded M. Millet, and is engaged in terminating the interesting work of restoring the Château of Saint-Germain-en-Laye.

The Northern and Eastern façades are entirely finished, and the rooms in this part of the building, now form the Gallo-Roman Museum.

The greater part of the Southern façade is restored, as also the chapel of Saint-Louis.

It only remains to complete this part, and to commence the Western façade, to which nothing has yet been done in the way of restoration.

Lectures, documents of the « École des Ponts et Chaussées » and of the School of Mines, and works on Engineering, published by M. Dunod, publisher to the « Corps des Ponts et Chaussées » and the Mines.

For the « *École des Ponts et Chaussées* », see page 331.

For the « *École des Mines* », see page 437.

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